APRIL 1, 2004

City of Stockton
San Joaquin County

Pathogen Plan

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1.0 INTRODUCTION

The federal Clean Water Act requires states to develop water cleanup plans for "impaired" rivers, lakes and streams. Impaired waters are those that do not meet water quality standards. Recent monitoring efforts have identified bacteria (pathogens) as an impairment to seven waterbodies within the Stockton Urbanized Area (this includes the City of Stockton [City] and portions of San Joaquin County [County]). In addition, the City and County (Permittees) received an National Pollutant Discharge Elimination System (NPDES) permit (Permit) covering discharges from the storm drain system. The permit requires the Permittees to develop a Pathogen Plan to address the bacteria within six of these waterbodies. The Pathogen Pollution Prevention Plan (Pathogen Plan) presented herein describes and reviews current conditions relevant to bacteria loadings, identifies strategies to identify the bacterial sources and controls for mitigating the sources. Implementation of the plan will address bacterial pollution in the Stockton urbanized area by mitigating the controllable sources.

1.1 Permit Requirements

Provision D.18.b of the Permit requires that the Permittees develop a control program to address pathogen impairment of streams by implementing a Pathogen Plan that addresses the identification, monitoring and mitigation of pathogen sources. According to provision D.18.b the Permittees must address pathogen loading by working with other interested stakeholders in identifying areas/and or activities which contribute high pathogen concentrations, identifying and developing suitable BMPs, and developing policies, procedures and/or ordinances to implement the Pathogen Plan. The section also states that the Permittees will assist the Regional Board in completing the Total Maximum Daily Load as it relates to bacteria – impaired waterbodies.

1.2 Overview

The Permittees have jurisdiction over and/or maintenance responsibilities for storm drains in the Stockton Urbanized Area. The discharge consists of surface runoff generated from various land uses that discharge into storm drains, which in turn empty to rivers and sloughs. The waterbodies in questions are protected for recreational uses, including boating, fishing, water skiing and swimming.

1.2.1 Impaired Waterbodies

The State Board has designated seven waterbodies within the Stockton Urbanized Area as being impaired by pathogens:

Mosher Slough
Five-Mile Slough
Lower Calaveras River
Smith Canal
Mormon Slough
Walker Slough
Deep Water Ship Channel

Smith Canal, Five Mile Slough and the urbanized portion of Mormon Slough receive storm water runoff only from the Stockton Urbanized Area. In addition to storm water runoff from the Stockton Urbanized Area, Calaveras River, Mosher Slough, and Walker Slough receive storm water runoff from agricultural areas upstream of the Stockton Urbanized Area. In most areas of the Stockton Urbanized Area, dry weather flow and storm water runoff flow by gravity to pump stations where the flows are released to sloughs/rivers. The sloughs drain westerly into the San Joaquin River, which runs along the western side of the Stockton Urbanized Area. The quality and quantity of these discharges vary considerably and are affected by hydrology, geology, land use, season, and sequence and duration of hydrologic events. The major impaired waterbodies in the Stockton urbanized area are shown in Figure 1.

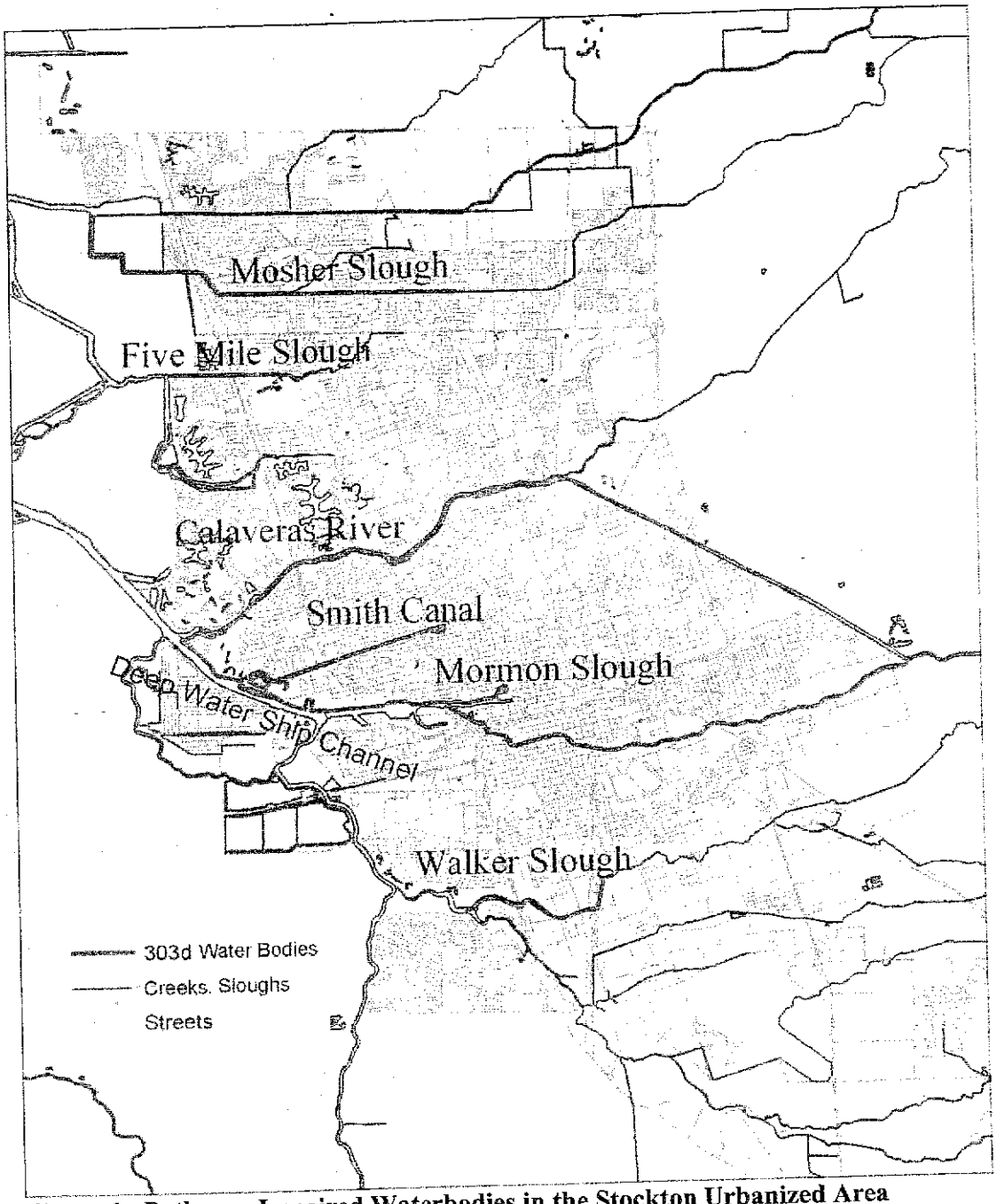


Figure 1. Pathogen Impaired Waterbodies in the Stockton Urbanized Area

1.2.2 Pertinent Water Quality Objectives

The State through the Regional Water Quality Control Boards establishes Basin Plans for the major watersheds of California. Basin Plans identify the beneficial uses of the waterbodies within the major watersheds and the water quality objectives required to

protect these beneficial uses. For the San Joaquin River in the vicinity of the Stockton Urbanized Area, the Regional Board has identified the following primary beneficial uses:

Recreational Uses (REC-1 and REC-2)
Fishing
Drinking water (MUN)

For recreational uses the Regional Board has established water quality objectives for bacteria. In deriving the bacteria water quality objective, the Regional Board considers differences in the risk of human exposure (immersion vs. contact), epidemiological research, and the need to use indicator organisms since it not yet feasible to test for the presence of all disease-causing microorganisms. Bacteria objectives therefore differ for water bodies with different beneficial uses.

The current basin plan objectives are based on fecal coliform and are:

> *In waters designated for contact recreation (REC-1), the fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed a geometric mean of 200/100 ml, nor shall more than ten percent of the total number of samples taken during any 30-day period exceed 400/100 ml.*

Regional Board staff recently recommended that the objectives for bacteria in waters used for contact recreation (REC-1) be modified to reflect those specified by the US Environmental Protection Agency (USEPA) in its "Ambient Water Quality Criteria for Bacteria – 1986" (USEPA, 1986). The updated objective is based on using the indicator organism, *E. coli* and was adopted by the Regional Board on September 6, 2002 in Resolution R5-2002-0150.

The new water quality objectives for bacteria for water bodies designated as REC-1 are as follows:

> *In all waters designated for contact recreation (REC-1), the E. coli concentration, based on a minimum of not less than five samples equally spaced over a 30-day period, shall not exceed a geometric mean of 126/100 ml and shall not exceed 235/100 ml in any single sample.*
>
> *If any single sample limits are exceeded for E. coli, the Regional Water Board may require repeat sampling on a daily basis until the sample falls below the single sample limit or for 5 days, whichever is less, in order to determine the persistence of the exceedance.*
>
> *When repeat sampling is required because of an exceedance of any one single sample limit, values from all samples collected during that 30-day period will be used to calculate the geometric mean.*

Additionally, the California Department of Health Services (CDHS) has adopted regulations for recreational waters and beaches for single samples of total coliform bacteria of 10,000 Most Probable Number (MPN) per 100 milliliters (mL) and of 1,000 MPN per 100 ml for 30-day log mean of sample levels (Title 17 California Code of Regulation section 7958). CDHS is also considering guidelines that include limits for single samples of *E. coli* of 235 MPN per 100 milliliters.

1.3 Pathogen Plan Objectives

Pursuant to the requirements set out in Section D 18.b of the permit, the Permittees are required to develop and implement a pathogen pollution prevention plan (Pathogen Plan).

The Pathogen Plan must include the following:

- Identification of areas and/or activities which contribute high pathogen concentrations in stormwater
  - Compile and evaluate all available pathogen monitoring data
  - Develop a GIS based decision support application for characterizing drainage basins and potential pathogen sources and/or activities
  - Develop listing of typical sources and/or activities that contribute to high pathogen concentrations
- A monitoring program for assessing the contribution of pathogens from both natural and anthropogenic sources
  - Identify monitoring sites
  - Determine frequency and extent of monitoring, sample handling procedures, analytical methods, quality assurance procedures, data management and reporting requirements
- A BMP implementation strategy to address controllable sources
- Strategies to identify and develop policies, procedures and/or ordinances to implement the above objectives
- Schedule and milestone dates for implementation of the Pathogen Plan
- Recommendations and/or performance standards for assessing effectiveness
- Strategies for participating in stakeholder forums and working with the San Joaquin County Environmental Health Department

1.4 Organization of Pathogen Plan

This work plan is divided into three major components:

- **Current Conditions** – this section summarizes the bacteria monitoring results and identifies those policies and procedures currently used to control bacteria sources.

- **Assessment of Current Conditions** – this section evaluates the monitoring results in relation to potential sources of bacteria. It also summarizes current microbial source tracking methodology and presents an overview of best management practices useful in controlling bacteria.

- **Pathogen Plan** – this section summarizes the strategies to be used in identifying bacteria sources and implementing BMPs to mitigate their impact.

Table 1. Summary of Land Uses within the Major Drainage Areas.

Drainage Area	Urbanized Drainage Area in Acres	Land Uses					Comments
		% Residential	% Commercial	% Industrial	% Mixed Urban	% Open Space (1)	
Five Mile Slough	16,121	44.4	11.2	0.0	22.3	22.1	No upstream contribution
Calaveras River	48,210	37.5	9.9	0.7	8.3	43.6	Significant upstream contribution
Mormon Slough	33,319	39.2	31.2	12.9	12.1	4.6	No upstream contribution
Mosher Slough	51,524	21.1	3.2	0.5	2.6	72.6	Significant upstream contribution
Smith Canal	36,342	71.5	18.3	2.1	7.0	1.2	No upstream contribution
Walker Slough	38,267	42.1	12.9	5.9	11.5	27.8	Limited upstream contribution

(1) Includes: Cropland, Pasture, Herbaceous Rangeland, Orchards, Groves, Vineyards, Nurseries, Streams, and Canals

2.0 CURRENT CONDITIONS

2.1 Urban Environment

The population of Stockton was estimated to be 262,835 residents as of July 1, 2002. In addition, the Stockton Urbanized Area is undergoing tremendous new development and is projected to increase to a population of more than 350,000 by the year 2025 (Census Bureau). This increased development and urbanization causes increases in pollutant loads, runoff volume and discharge velocity. Natural vegetated soil can both absorb rainwater and remove pollutants providing an effective natural purification process. In contrast, pavement and concrete can neither absorb water nor remove pollutants, and thus any purification characteristics are lost. Also, urban development creates new pollution sources as the increased density of human population brings proportionately higher levels of municipal sewage waste, pet wastes, trash, and other anthropogenic pollutants.

2.2 Hydrological Environment

The major drainage watersheds in the Stockton Urbanized Area are Bear Creek, Mosher Slough, Five Mile Slough, Fourteen Mile Slough, the Calaveras River, Smith Canal the Deep Water Channel, Mormon Slough, Walker Slough, Duck Creek, and Little John Creek. Of these waterbodies, seven are listed as being impaired by pathogens. These Include:

Mosher Slough
Five Mile Slough
The Lower Calaveras River
Smith Canal
Mormon Slough
Walker Slough
The Deep Water Channel

Smith Canal and Five Mile Slough receive storm water runoff only from the Stockton Urbanized Area. Additionally, the Calaveras River, Mosher Slough, and Walker Slough receive storm water runoff from agricultural areas upstream of the Stockton Urbanized Area. All of these water bodies discharge to the San Joaquin River and are tidal freshwater. In most areas of the Stockton Urbanized Area, dry weather flow and storm water runoff are released to sloughs/rivers. These drain westerly into the San Joaquin River, which runs along the western side of the Stockton Urbanized Area. The quality and quantity of these discharges vary considerably and are affected by hydrology, geology, land use, season, and sequence and duration of hydrologic events.

The summary of land uses within the drainage areas of the listed waterbodies being examined is provided in Table 1.

2.3 Review of Monitoring Results

In the following subsections, the bacteriological quality of six 303(d) listed waterbodies being examined by this effort is discussed (Note: the Deep Water Channel, though 303(d) listed for pathogens, is outside the scope of this plan). Over the years, the City of Stockton and the Deltakeeper have conducted extensive bacteria monitoring efforts. The location of these monitoring efforts are presented in Figure 2. The monitoring results presented in the following subsections indicate that all six 303(d) listed waterbodies have high bacteria concentrations on a regular basis. Although the presence of indicator bacteria does not prove that disease-causing bacteria, viruses, or protozoa are present in the environment, their presence does show that contamination by fecal material has likely occurred. High concentrations of bacteria have the potential to reduce the recreational value of these waterbodies by posing an increased risk of exposure to harmful bacteria and the associated adverse effects to humans who come in contact with the water.

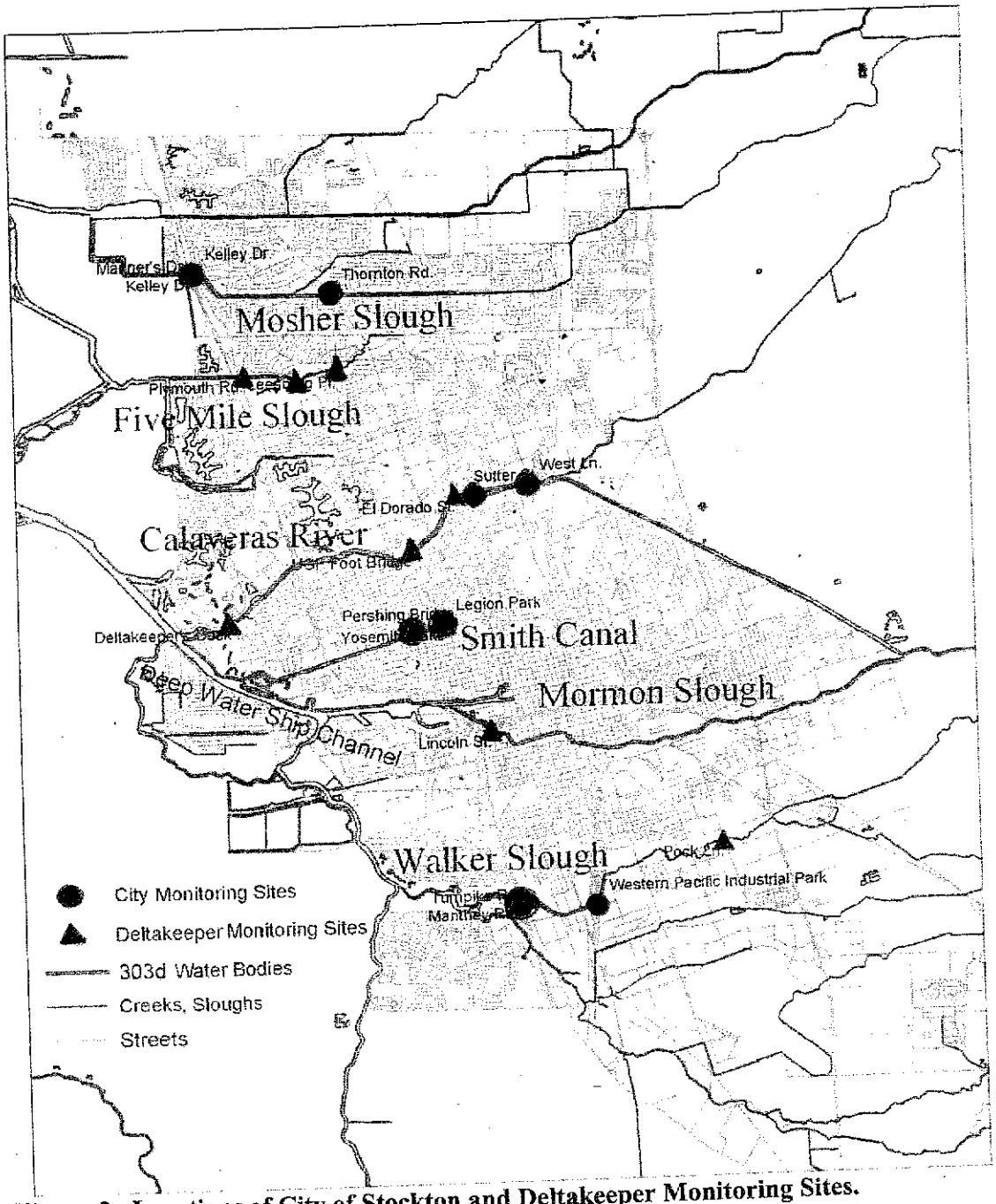


Figure 2. Locations of City of Stockton and Deltakeeper Monitoring Sites.

2.3.1 Mosher Slough

Between May 2000 to February 2004 the Deltakeeper sampled for bacteria at two sampling locations in Mosher Slough. Both sampling sites are located at the lower end of Mosher Slough. A total of 63 samples were collected. The majority of samples collected at both sites exceeded the CDHS 30 day criterion (1000 MPN/100 ml) for total coliform and the recommended *E. coli* criterion (126 MPN/100 ml). The measured bacteria

densities in the samples were high during the entire sampling period. The geometric means for *E. coli* and total coliform levels measured at the Mariner's Drive sampling location are 348 MPN per 100 ml and 16,952 MPN per 100 ml, respectively. The City's monitoring program also showed elevated bacteria levels in receiving waters of Mosher Slough. The City's monitoring program sampled Mosher Slough five times between April 2003 and February 2004, with geometric means of 39,121 MPN per 100 ml for total coliform, 5,416 MPN per 100 ml for fecal coliform, and 4,351 MPN for 100 ml for *E. coli*. Outfall discharges at Kelley Drive and Thornton Road into Mosher Slough also had high concentrations of bacteria. The City's monitoring program sampled the outfall at Kelley Drive twelve times between November 1998 and February 2004, with geometric means of 78,885 MPN per 100 ml for total coliform and 17,924 MPN per 100 ml for fecal coliform. The outfall at Thornton Road was monitored seventeen times between November 1998 and February 2004, with geometric means of 112,846 MPN per 100 ml for total coliform and 34,093 MPN per 100 ml for fecal coliform. Sampling site locations and drainage land uses for Mosher Slough are presented in Figure 3.

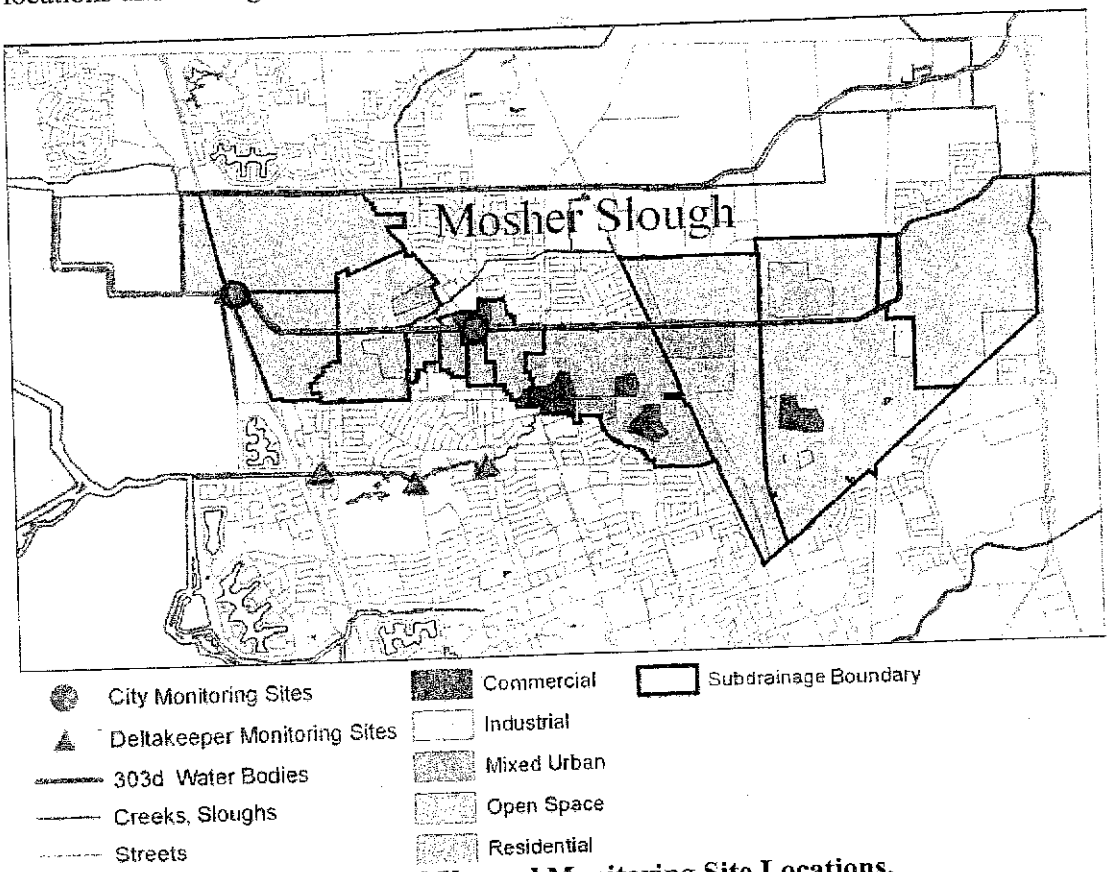


Figure 3. Mosher Slough Land Use and Monitoring Site Locations.

2.3.2 Five-Mile Slough

Deltakeeper collects bacteria data from two locations on Five Mile Slough. One sampling location (downstream) is near the mouth of the slough (at the confluence with Fourteen Mile Slough) and the other sampling location (upstream) is located at

Alexandria Place, approximately 1.5 miles upstream of the mouth of the slough. A total of 62 samples collected from Five Mile Slough from April 2000 to February 2004 were analyzed for *E. coli* and total coliform. Geometric means of the bacteria counts have been calculated using the data submitted by Deltakeeper. The geometric means for *E. coli* and total coliform levels measured at the downstream sampling location are 130 MPN per 100 ml and 27,789 MPN per 100 ml, respectively. The geometric mean for *E. coli* levels measured at the upstream sampling location is 147 MPN per 100 ml, which exceeds the U.S. EPA criterion of 126 MPN per 100 ml. The City of Stockton does not monitor Five Mile Slough for bacteria. Sampling site locations and drainage land uses for Five Mile Slough are presented in Figure 4.

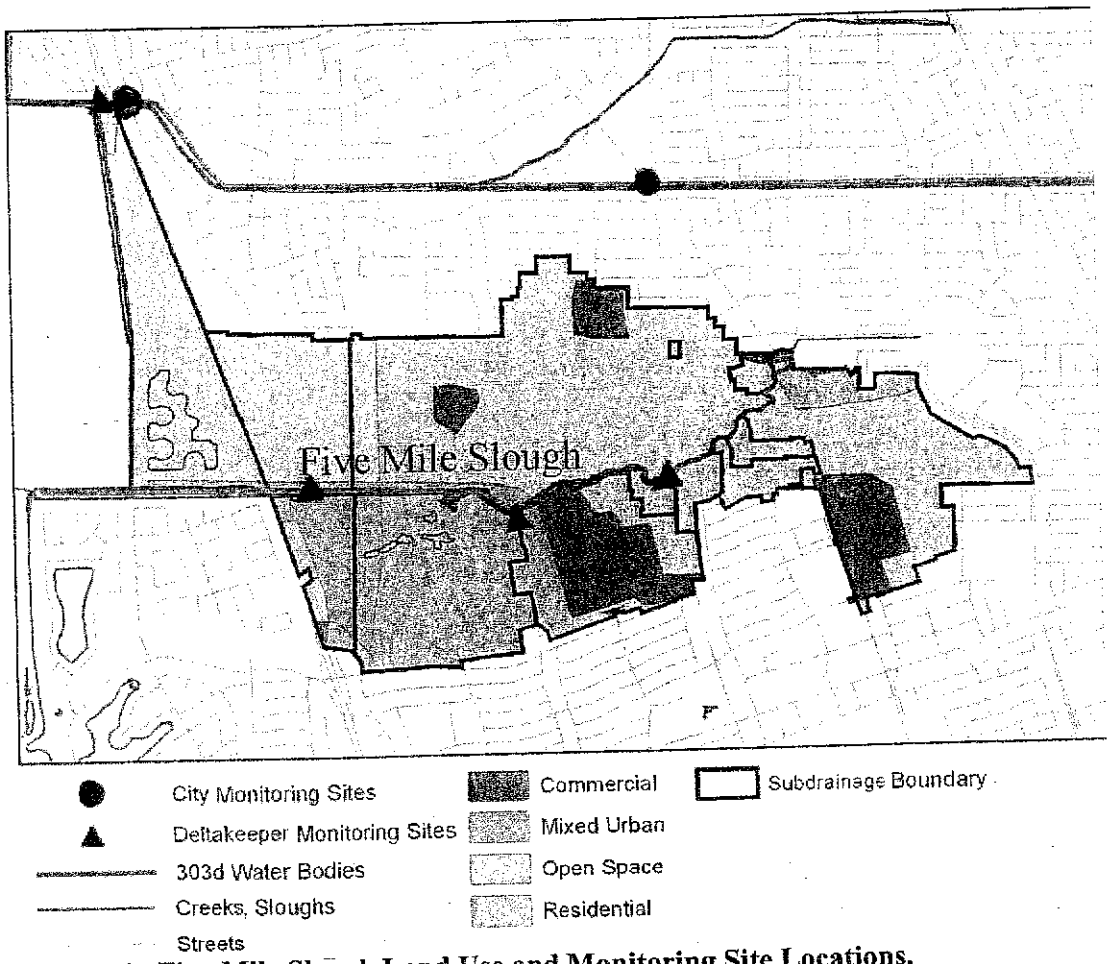


Figure 4. Five Mile Slough Land Use and Monitoring Site Locations.

2.3.3 Lower Calaveras River

Deltakeeper collects bacteria data from two locations on the lower Calaveras River. One sampling location is near the mouth of the river and the other is approximately four miles upstream. A total of 53 samples were collected at the upstream location from August 2000 to February 2004, and seven samples were collected at the downstream location from June 2000 to February 2004. Geometric means of the bacteria counts have been calculated using the data submitted by Deltakeeper. The geometric mean for *E. coli* was

215 MPN per 100 ml for samples collected at the upstream location (exceeding the USEPA criterion of 126 MPN per 100 ml). The geometric mean for *E. coli* samples collected at the downstream location was 48 MPN per 100 ml. However, individual *E. coli* measurements at the downstream site have exceeded the USEPA single sample criterion of 235 MPN per 100 ml. The geometric mean for total coliform was 2,419 MPN per 100 ml for samples collected at the upstream location. The geometric mean for total coliform for samples collected at the downstream location was 15,904 MPN per 100 ml (exceeding the CDHS 30-day average of 1,000 MPN per 100 ml. and the single sample criterion of 10,000 MPN per 100 ml as well).

The City's monitoring program sampled the Calaveras River five times between April 2003 and February 2004, with geometric means of 11,642 MPN per 100 ml for total coliform, 1,285 MPN per 100 ml for fecal coliform, and 1,194 MPN for 100 ml for *E. coli*. All exceeded 30 day average criteria. Single sample criteria were also exceeded on several occasions. Outfall discharges at West Lane and Sutter Street into the Calaveras River also had high concentrations of bacteria. The City's monitoring program sampled the outfall at West Lane seventeen times between November 1998 and February 2004, with geometric means of 75,689 MPN per 100 ml for total coliform and 7,512 MPN per 100 ml for fecal coliform. The outfall at Sutter Street was monitored twelve times between November 1998 and February 2004, with geometric means of 170,188 MPN per 100 ml for total coliform and 16,353 MPN per 100 ml for fecal coliform. Sampling site locations and drainage land uses for the Lower Calaveras River are presented in Figure 5.

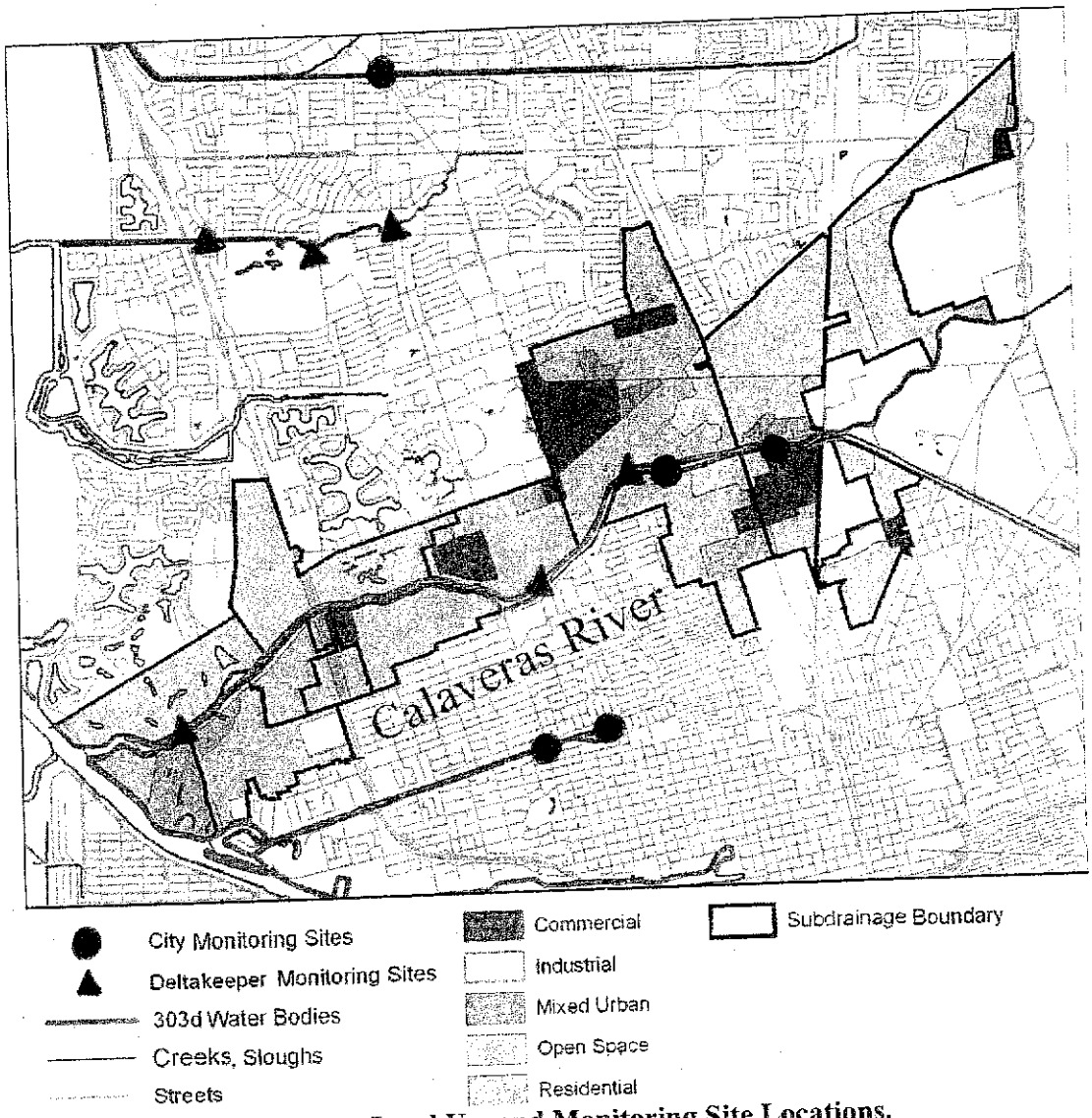


Figure 5. Calaveras River Land Use and Monitoring Site Locations.

2.3.4 Smith Canal

Deltakeeper submitted bacteria data for Smith Canal from two sampling locations. The sampling locations are located at the upper terminus of the canal at Yosemite Lake and approximately one-quarter mile downstream at the Pershing Bridge. Geometric means have been calculated using the data submitted by Deltakeeper. The calculated geometric mean for the *E. coli* levels in samples collected from the Yosemite Lake location is 882 MPN per 100 ml, which exceeds the USEPA criterion of 126 MPN per 100 ml. The calculated geometric mean for the *E. coli* levels measured in samples collected from the Pershing Bridge is 2,622 MPN per 100 ml, which also exceeds the USEPA criterion of 126 MPN per 100 ml. The calculated geometric mean for the total coliform levels measured in samples collected from the Yosemite Lake location is 31,230 MPN per 100 ml, which exceeds the CDHS 30-day criterion of 10,000 MPN per 100 ml. The single sample criterion of 1,000 MPN per 100 ml was also exceeded on several occasions. The

calculated geometric mean for the total coliform levels measured in samples collected from the Pershing Bridge sampling location (approximately one-quarter mile downstream from the Yosemite Lake) is 16,413 MPN per 100 ml.

The City's monitoring program sampled Smith Canal five times between April 2003 and February 2004, with geometric means of 8,312 MPN per 100 ml for total coliform, 3,231 MPN per 100 ml for fecal coliform, and 1,627 MPN for 100 ml for *E. coli*. Outfall discharges at Legion Park into Smith Canal also had high concentrations of bacteria. The City's monitoring program sampled the outfall at Smith Canal five times between April 2003 and February 2004, with geometric means of 221,432 MPN per 100 ml for total coliform and 17,716 MPN per 100 ml for fecal coliform. Sampling site locations and drainage land uses for Smith Canal are presented in Figure 6.

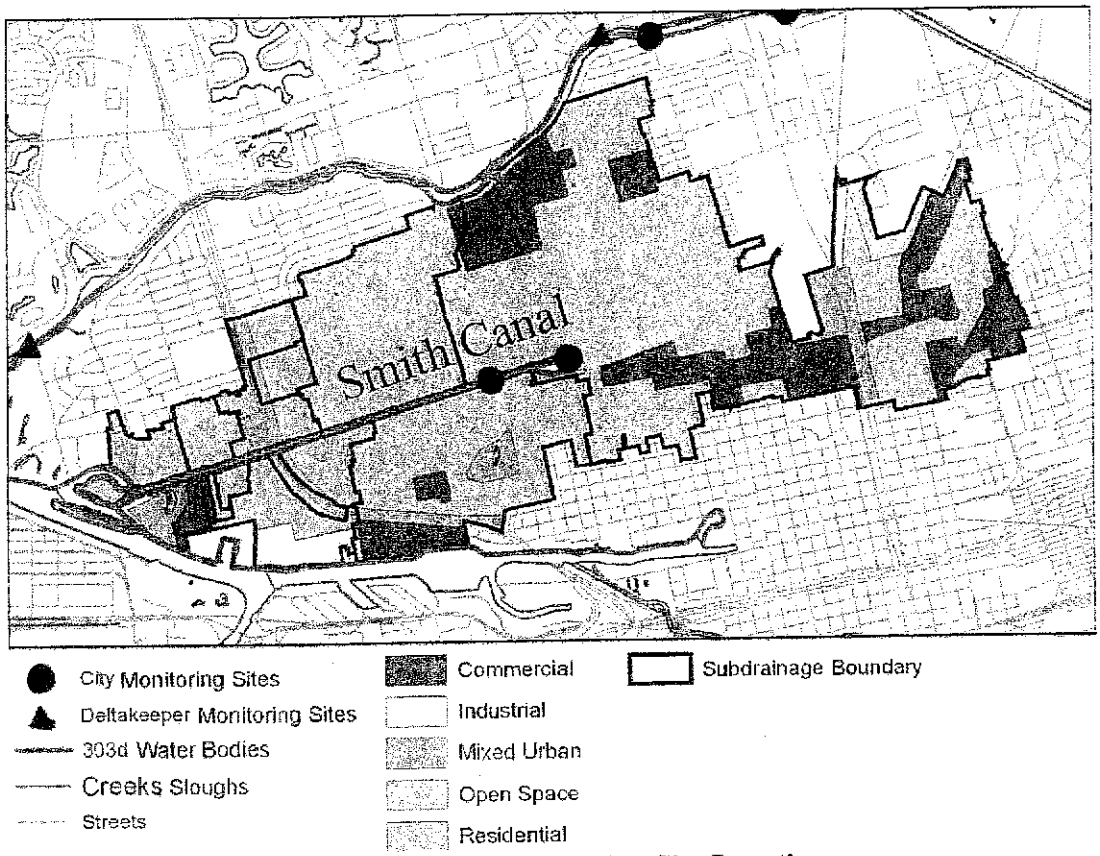


Figure 6. Smith Canal Land Use and Monitoring Site Locations.

2.3.5 Mormon Slough

Deltakeeper submitted bacteria data for Mormon Slough from one sampling location, approximately one mile upstream from the confluence with the Stockton Deep Water Channel. A total of 68 samples collected from June 2000 to February 2004 were analyzed. The calculated geometric mean for the *E. coli* levels is 1,144 MPN per 100 ml, which exceeds the USEPA criterion of 126 MPN per 100 ml. Additionally, the single sample *E. coli* criteria (235 MPN per 100 ml) was exceeded on several occasions. The

calculated geometric mean for the total coliform levels is 16,725 MPN per 100 ml, which exceeds the U.S. DHS 30-day criterion of 1,000 MPN per 100 ml and the single sample criteria of 1,000 MPN per 100 ml. The City does not monitor Mormon Slough for bacteria. Sampling site locations and drainage land uses for Mormon Slough are presented in Figure 7.

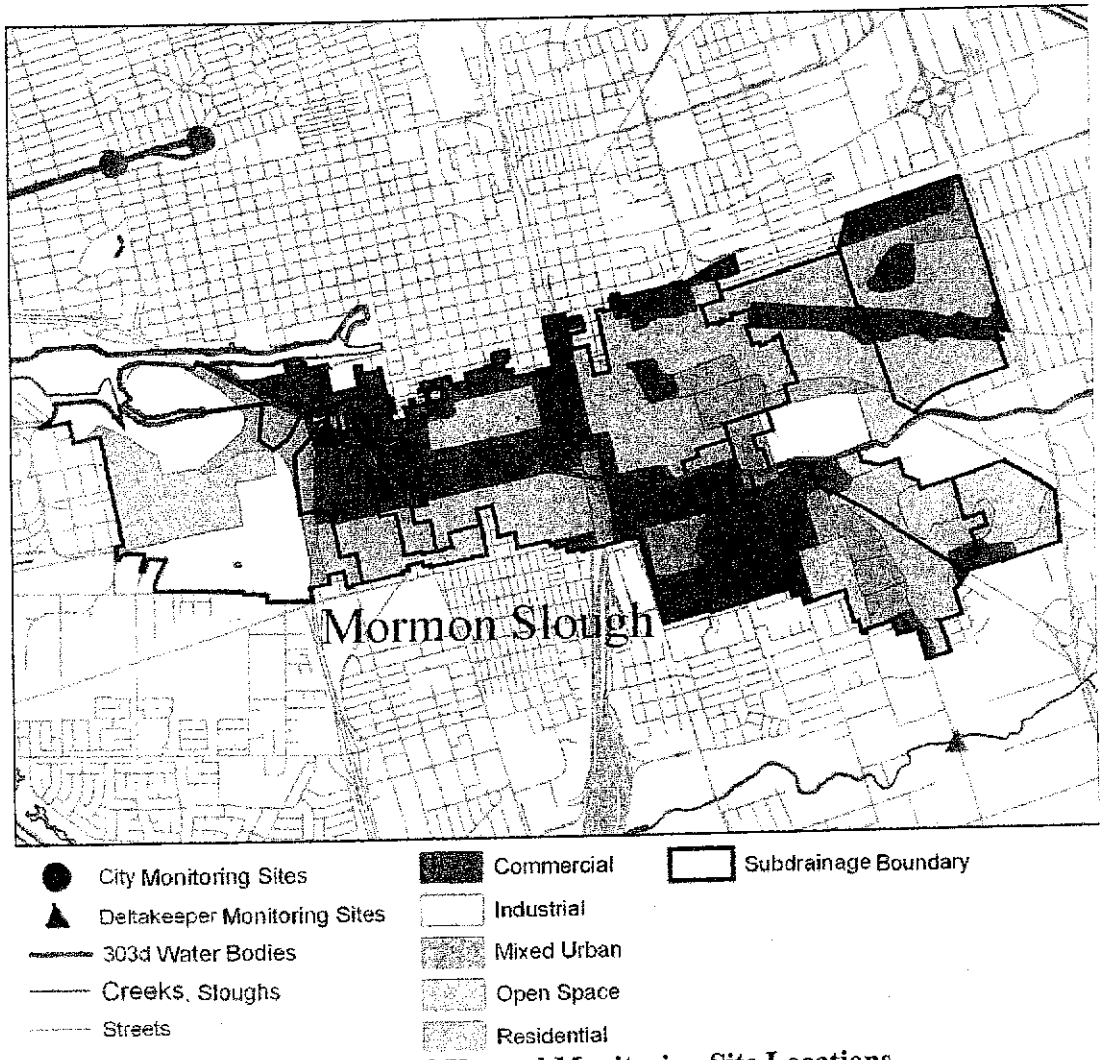


Figure 7. Mormon Slough Land Use and Monitoring Site Locations.

2.3.6 Walker Slough

Deltakeeper samples bacteria on Walker Slough from three sampling locations. Sixty samples were collected from these locations between October 2000 and February 2004. For both sites, geometric means of the bacteria counts have been calculated using the data submitted by Deltakeeper. The calculated geometric mean for *E. coli* in samples collected from the two downstream locations (Manthey Road and Turnpike Road, both located near I-5) is 556 MPN per 100 ml, which exceeds the USEPA criterion of 126 MPN per

100 ml. The calculated geometric mean for *E. coli* in samples collected from the upstream location (Duck Creek at Pock Lane) is 1,182 MPN per 100 ml, which also exceeds the USEPA criterion.

The City's monitoring program sampled Duck Creek (upstream of Walker Slough) five times between April 2003 and February 2004, with geometric means of 8,353 MPN per 100 ml for total coliform, 814 MPN per 100 ml for fecal coliform, and 846 MPN for 100 ml for *E. coli*. These samples were actually taken at the Western Pacific Industrial Park. Outfall discharges at the Western Pacific Industrial Park also had high concentrations of bacteria. The City's monitoring program sampled the outfall at the Western Pacific Industrial Park seventeen times between November 1998 and February 2004, with geometric means of 77,261 MPN per 100ml for total coliform and 9,763 MPN per 100 ml for fecal coliform. Sampling site locations and drainage land uses for Walker Slough are presented in Figure 8.

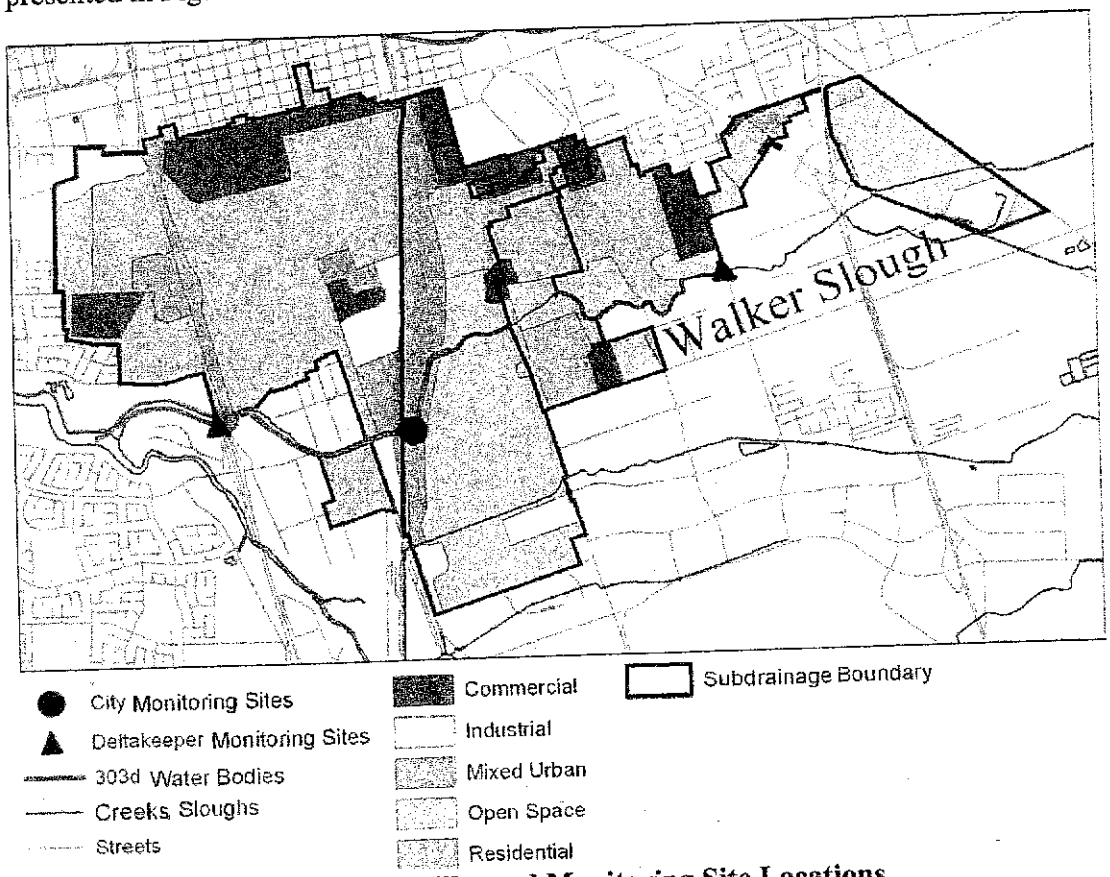


Figure 8. Walker Slough Land Use and Monitoring Site Locations.

2.4 Review of Existing Policies and Procedures to Control Bacteria Sources

This sub-section summarizes the existing policies and procedures that are in place within the jurisdictional limits of the Permittees that assist in controlling urban sources of bacteria. Although they are briefly described below, many of the policies and procedures

are described in additional detail within the Permittees' Stormwater Management Plans (SWMP 2003).

The potential urban sources of bacteria that have been identified and addressed within this section include the following:

- Illicit Discharges
- Sanitary Sewer Overflows (SSOs)
- Storm Drain System and Street Maintenance
- Landscape Management Practices
- Domestic Pet Feces
- Livestock/Equestrian
- Vessel Holding Tank Discharges

2.4.1 Illicit Discharges

An illicit discharge is any discharge to the storm drain system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term "illicit discharge" includes all non storm-water discharges except those discharges that are conducted pursuant to an NPDES permit or those discharges specifically authorized by the Regional Board. Illicit discharges also include illegal connections which are defined as illegal and/or improper connections to a storm drain system or receiving water. An example would be a sanitary sewer connection to the storm drain.

Since illicit discharges and illegal connections can be a significant source of bacteria, the Permittees have developed and implemented a comprehensive program for detecting, responding to, investigating and eliminating these types of connections/discharges (see Section 2 in the SWMP).

Legal Authority

In order to have an effective program, the Permittees have adopted various ordinances to ensure that they have adequate legal authority to regulate the discharge of pollutants to municipally owned and operated areas including the storm drain system. The Ordinances are primarily focused around solid waste/litter control as well as the stormwater management. The Ordinances that have been adopted include the following:

Solid Waste/Litter

- The City enacted a Collection of Garbage, Rubbish, Waste Matter, Industrial Waste, Garden Refuse and Swill Ordinance (Chapter 7, Part II, Sections 7-050 to 7-077.24) to address issues associated with the depositing, collection and disposal of these wastes.

Stormwater

- The City enacted a Stormwater Management and Discharge Control Ordinance No. 013-95 (Chapter 7, Part VIII, Section 7-800 to 7-858.2) to specifically control

stormwater runoff quality. This ordinance both complements and supplements the existing ordinances and established uniform requirements for protecting and enhancing the water quality of their watercourses, water bodies and wetlands in a manner consistent with the Clean Water Act.

- The County enacted a Stormwater Management and Discharge Control Ordinance No. 3966 (codified in Title 5, Division 10) to specifically control stormwater runoff quality. This ordinance established uniform requirements for protecting and enhancing the water quality of the waters of San Joaquin County in a manner consistent with the Clean Water Act.

Illicit Discharge Procedures

The Permittees have implemented a number of procedures to assist them in detecting illicit discharges. Once the discharges have been detected the Permittees eliminate the discharge and conduct any necessary investigations and/or clean up activities. The procedures include the following:

- Public Reporting - The Permittees have both established 24-hour Hotlines to encourage the public to report problems and to allow their staff to respond in a timely manner.

- Dry Weather Monitoring - The Permittees conduct annual dry weather field screening. The primary purpose of the monitoring program is to identify new dry weather flows as well as "hot spots". Any significant discharges found are sampled and tested for detergents to check for illegal discharges.

- Field Crew Inspections - During their normal maintenance activities, field staff identify signs of previous, current, or potential non-stormwater discharges/connections or illegal dumping into the storm drain system. Once discovered, the field staff notify the appropriate department/division for the follow-up investigation.

Illegal Connection Procedures

The Permittees also detect, investigate and eliminate illegal connections to the storm drain system. If the Permittees encounter a potential illegal connection that warrants further investigation, they have a number of methods that may be used to investigate the problem including dye or smoke tests, video (TV), construction certification, and an inspection program. If an illicit discharge is discovered, the Permittees respond accordingly by investigating and conducting any clean up efforts that may be necessary.

Public Education and Outreach Materials

The Permittees have developed a number of public education and outreach materials that identify appropriate practices for preventing illicit discharges and illegal connections. The public education and outreach materials that the Permittees routinely distribute that address sources of bacteria include the following:

Pollution Prevention Tips for Businesses
Pollution Prevention In Your Garden
Pollution Prevention Outside Your Home
Pollution Prevention On Your Boat
Pollution Prevention Landscaping/Pools
Dog Waste Poster

2.4.2 Sanitary Sewer Overflows (SSOs)
Sanitary sewer overflows (SSOs) can be defined as any discharge of sewage from a sanitary sewer collection system prior to reaching the wastewater treatment plant. The SSOs contain bacteria and disease-causing microorganisms and other contaminants that can contribute to a public health threat. SSOs are also rich in environmental nutrients such as nitrates and phosphates which are implicated in water quality conditions leading to nutrient enrichment, algal blooms, hypoxia and fish kills.

Since SSOs can be a significant source of bacteria, the Permittees have developed and implemented a comprehensive program for preventing and responding to these types of discharges (see Section 4 in the SWMP).

Legal Authority
In order to have an effective program, the Permittees have adopted ordinances to ensure that they have adequate legal authority to regulate discharges from the sanitary sewer system and prevent the waste from entering the municipal storm drain system. The Ordinances that have been adopted include the following:

- The Permittees have both enacted Stormwater Management and Discharge Control Ordinances (Section 2.3.1.1). These ordinances prohibit the discharge of sewage from entering the municipal storm drain system.

- The City enacted a Wastewater Discharges and Treatment Works Ordinance (Chapter 7, Part III, Sections 7-088 to 7-088.9) to specifically address issues associated with discharges to or from the sanitary sewer system.

Sanitary Sewer Overflow Procedures
The Permittees have implemented a number of procedures to assist them in preventing and responding to SSOs. Once the SSO has been reported, the Permittees respond, eliminate the discharge and conduct any necessary clean up activities. The procedures include the following:

- Public Reporting - The Permittees have both established 24-hour Hotlines to encourage the public to report problems and to allow their staff to respond in a timely manner.

- Response Plan - The Permittees have developed and implemented Sanitary Sewer Overflow (SSO) Response Plans in order to minimize potential impacts from sanitary

sewer overflows. The Plans generally address the investigation of complaints, containment, and notification to appropriate agencies.

- Inspections - The City's program to limit the infiltration of sewage from the sanitary sewer and septic systems to the storm drain system primarily consists of inspecting the construction of sanitary sewer lines, televising existing storm drain lines, and responding to reported or potential problems. If cross connections or infiltration is suspected to a storm drain, it is televised.

2.4.3 Storm Drain System and Street Maintenance

As a part of their normal operations, the Permittees conduct a number of storm drain and street maintenance activities that remove pollutants. The storm drain maintenance activities include cleaning the catch basins, pump stations and detention basins. The removal of trash and debris from the streets and storm drains (including animal wastes, dead animals or food wastes) assists in decreasing the bacteria levels.

Since the trash and debris on and in the streets and storm drains can be a significant source of bacteria, the Permittees have developed and implemented a comprehensive program for managing these areas (see Section 4 in the SWMP).

Storm Drain System and Street Maintenance Procedures

The Permittees have implemented a number of procedures to assist them in managing the trash and debris on and in the streets and storm drains. The procedures include the following:

Storm Drain System

- Catch Basin Stenciling - The Permittees stencil the catch basins so that the general public understands that the water that enters the catch basins flows untreated to the creeks, rivers, bays, etc. By stenciling or marking the catch basins, the Permittees educate the public and prevent materials (such as dog waste) from being deposited in them.

- Catch Basin Inspection and Cleaning - The Permittees established prioritization criteria for the inspection and cleaning of the catch basins. Depending upon the area, the catch basins are either cleaned once prior to the wet season or inspected annually and cleaned as necessary. If evidence of an illicit discharge is found, the location is referred to the appropriate responder.

- Detention Basins and Pump Station Inspection and Cleaning - The Permittees inspect and clean the detention basins and pump stations. By removing the trash and debris from the wet wells and stations, the potential for these locations to be significant sources of bacteria are decreased.

- Special Use Permit Conditions - The Permittees have developed special use permit conditions for the proper handling and disposal of trash and litter at events that can be

reasonably expected to generate substantial quantities of trash and litter. Since many of these events generate food wastes and trash, the special use permit conditions may prevent the events from becoming significant sources of bacteria.

Street Maintenance

- Street Sweeping Program - The Permittees established prioritization criteria for the street sweeping program. Depending upon the area, the streets are generally swept either once or twice per month. The street sweeping activities assist in decreasing the bacteria levels by removing the trash and debris that would otherwise end up in the catch basins or storm drain system.

2.4.4 Landscape Management Procedures

As a part of their normal operations, the Permittees manage a number of landscaped areas within public recreational facilities, public rights-of-way, and municipal facilities. In order to properly manage these areas and maintain plant health, fertilizers often need to be applied. Used properly, fertilizers provide important nutrients. Used improperly, some fertilizers such as organic soil amendments can potentially become a source of bacteria. In addition, the improper disposal of landscape waste may provide a suitable habitat for the re-growth of bacteria.

Since some types of fertilizers such as organic fertilizers/soil amendments may be a significant source of bacteria, the Permittees have developed and implemented a comprehensive Landscape Management Program (see Section 4 in the SWMP). The Procedures identify standard protocols for the administration, storage and application of fertilizers in the public right-of way or at other municipal owned/operated facilities.

2.4.5 Domestic Pet Feces

Domestic pet feces (primarily from cats and dogs) can be a significant source of bacteria if the feces are not picked up and disposed of properly. Pet feces left in outdoor areas can be washed into nearby catch basins, creeks, streams, etc. by irrigation or stormwater runoff where the feces provide a source of bacteria, viruses and parasites that may pose a risk to human health and the environment.

Since pet feces can be a significant source of bacteria, the Permittees have developed and implemented a number of procedures for managing these wastes.

Legal Authority

In addition to the general authorities that the Permittees have under the Stormwater Management and Discharge Control Ordinances, the Permittees have adopted ordinances to ensure that they have adequate legal authority to regulate how animal premises are maintained. The Ordinances that have been adopted include the following:

- The City enacted an Animals and Fowl – Public Pound Ordinance (Chapter 7, Part V, Sections 7-117 to 7-137.1) in part to address issues associated with the condition that pet owners must maintain the premises where animals are housed.

- The County has regulations on the number of animals allowed in zones relative to lot size. Additional regulations will be developed for consideration by the Board of Supervisors

Pet Waste Management Procedures

The Permittees have implemented a number of procedures to assist them in managing pet feces. The procedures include the following:

- Dog Waste Disposal Centers – Pet waste bags have been made available in some parks.

- Public Education – The Permittees have developed public education and outreach materials that identify appropriate practices for the management of pet feces. The materials that the Permittees routinely distribute include the following:

  Pollution Prevention Outside Your Home
  Dog Waste Poster

2.4.6 Livestock/Equestrian Feces

Livestock or equestrian feces can be a significant source of bacteria if the waste is not picked up and disposed of properly. Waste that is stored improperly or left uncovered in outdoor areas can be washed into nearby catch basins, creeks, streams, etc. by irrigation or stormwater runoff where it is left to decay. As it decays, the waste provides a source of bacteria, viruses and parasites that may pose a risk to human health and the environment.

Since livestock or equestrian waste can be a significant source of bacteria, the Permittees discuss these issues with property/facility owners when problems have been identified and provide them with procedures for the proper management of these wastes.

2.4.7 Vessel and Recreational Vehicle Holding Tank Discharges

Vessel and Recreational Vehicle holding tanks contain sewage and the chemical additives that are used to disinfect and deodorize the waste. As such, they may be a significant source of bacteria if the waste is not properly disposed of at a pump out or dump station.

Since holding tanks can be a significant source of bacteria if they are dumped illegally, the Permittees have developed and distributed public education and outreach materials that identify appropriate practices for the management of vessel holding tanks (Pollution Prevention – On Your Boat). In addition, the Permittees provide pump out stations/dump stations so that boat owners/operators can properly dispose of their vessel holding tank waste.

3.0 ASSESSMENT OF CURRENT CONDITIONS

3.1 Overview of Monitoring Results

Concentrations of bacteria that exceed standards were common in the waterbodies examined. However, this situation is not unique to the Stockton Urbanized Area. According to a recent nationwide study, bacterial contamination was ranked as the third most common cause for water-body impairment in the United States (Armitage et al, 1999).

A review of the bacteria monitoring data provided by the City and Deltakeeper (see Figures 3 – 8) fails to identify any particular location or source of fecal material as the cause of elevated bacteria concentration in the waterbodies examined. Sites in every waterbody consistently exceeded various criteria (see Table 2).

Bacteria concentrations in discharge may be somewhat linked to land use (see Table 3). High percent residential land use within a watershed appears to be associated with high total and fecal coliform geometric means in some sub-watersheds.

When ranked by overall geometric mean values, the Calaveras River receiving water sites generally ranked lower than other sites. There also does not appear to be any upstream/downstream trends in bacteria concentrations. Bacteria levels downstream were not always higher than concentrations upstream, and vice versa (see Table 2). Also, overall, no single waterbody appears to be more polluted than another. Rather, bacterial pollution appears to be ubiquitous.

To summarize, bacteria concentrations varied widely through the monitoring period, but frequently exceeded criteria. Land-use factors appear to play a role in determining bacterial concentrations at some sites.

Table 2. Characterization Monitoring Data from Receiving Water Sites

Drainage	Land Use Description	Receiving Water Sites(1)	Geometric Mean		
			Total Coliform	Fecal Coliform	E. coli
Mosher Slough	Significant Up-Stream Contribution, Primarily Open Space				
		Mariner's Dr. **	16,952		349
		Kelley Dr. *	39,121	5,416	4,351
		Kelley Dr. **	12,430		660
Five Mile Slough	Mixed Land Use, No Industrial				
		Plymouth Rd. **	27,789		130
		Alexandria Pl. **	24,192		88
		Leesburg Pl. **	6,131		147
Calaveras River	Significant Up-Stream Contribution, Large Open Space				
		Deltakeeper's Dock **	2,419		48
		UOP Footbridge **	15,904		215
		West Ln. *	11,642	1,285	1,194
Smith Canal	No Up-Stream Contribution, Heavily Residential				
		Pershing St. Bridge **	16,413		2,622
		Yosemite Lake **	31,230		882
		Legion Park *	8,312	3,231	1,627
Mormon Slough	Mixed Land Use, Minimal Open Space				
		Lincoln St. **	16,725		1,144
Walker Slough	Mixed Land Use, Primarily Open Space & Residential				
		Turnpike Rd. **	24,192		175
		Manthey Rd. **	15,717		556
		Western Pacific Industrial Park *	8,353	814	846

*City of Stockton, ** Deltakeeper

(1) Sites are listed by starting with the most downstream site within the drainage area and moving upstream.

Table 3. Characterization Monitoring Data from Discharge Sites

Discharge Site	Geometric Mean		Land Uses					Total Area in Acres
	Total Coliform	Fecal Coliform	% Residential	% Commercial	% Industrial	% Mixed Urban	% Open Space (1)	
Mosher Slough								
Kelley Dr.	78,885	17,924	1.3	0.0	0.0	0.0	98.7	5,708
Thornton Rd.	112,846	34,093	69.9	17.5	0.0	9.1	3.5	1,588
Calaveras River								
Sutter St.	170,188	16,353	68.0	4.9	0.0	16.0	11.0	3,916
West Ln.	75,689	7,512	8.2	16.8	0.9	8.2	65.9	6,540
Smith Canal								
Legion Park	221,432	17,716	66.2	27.2	0.8	4.1	1.8	20,086
Walker Slough								
Western Pacific Industrial Park	77,261	9,763	1.3	0.0	9.1	7.6	82.0	6,422

(1) Includes: Cropland, Pasture, Herbaceous Rangeland, Orchards, Groves, Vineyards, Nurseries, Streams, and Canals

3.2 Overview of Principle Sources of Bacteria/Fecal Material

Other studies in urban settings are instructive and several "typical" sources of pathogen pollution have been identified. These sources include urban litter, contaminated refuse, domestic pet and wildlife excrement and failing sewer lines.[1] It is also well known that for bacterial loading in urban streams; fecal bacteria densities are directly related to the density of housing, population, development, percent impervious area, and the density of domestic animals (Armitage et al, 1999).[2] Additionally, recreational areas and areas frequented by the homeless often have high bacteria counts.

In the Stockton Urbanized Area, several possible sources should be considered:

- Illicit discharges/illicit connections to the storm drain system
- Sanitary sewer exfiltration and malfunctioning sewage disposal systems
- Irrigation runoff from open space areas
- Domestic pet feces
    - Cats
    - Dogs - With an estimated population of several hundred per square mile in some urban locations, dogs contribute thousands pounds of pet droppings each day to the watershed.
- Wildlife feces
    - Birds - Populations of birds such as seagulls and some large waterfowl (such as ducks and Canada Geese) have exploded in recent years and may be an important potential source of bacteria.
    - Raccoons - According to urban naturalists, population densities of this adaptive nocturnal mammal may be greater in some urban settings than in the wild. They are known to use storm drain networks as their own "Intelligent Transportation System" to move from greenspace to greenspace.
- Bather defecation
- Improper disposal of wastes from boats
- Dry weather discharge through storm drains
- Agricultural activity adjacent to the urban area

Drainage from storm drains during dry weather periods contribute to the bacteria levels in receiving waters. In addition to temperature moderation, storm drains may also prevent die-off by shielding the bacteria from the sun's ultraviolet radiation. The influence of storm drains on bacteria problems can be explained in two possible ways. First, the density of animal feces in the storm drains can be quite high and may provide a constant source of bacteria as water passes over the fecal deposits. A second, and perhaps more likely explanation, is that fecal material is deposited in storm drains, bacteria are transported from the fecal material, become deposited in the storm drains, re-grow and contribute to the microbial film found in the storm drains. Clonal bacterial populations lift-off, or are scoured by moving water, and provide a continuous source, or inoculation, of bacteria to the discharging water.

Sediments are also important reservoirs for fecal coliform introduction to surface waters. Sufficient quantities of nutrients and carbon are generally available to support regrowth in storm drains.

Lastly, no city is immune to the problems of vagrancy and homelessness. The specter of human sources of fecal bacteria may be larger than previously believed. Also, leaking sanitary sewer lines or failing septic systems may be another cause of high bacteria levels.

3.3 Overview of Microbial Source Tracking Methods

One of the most important objectives of the Pathogen Plan is to develop a monitoring program for assessing the contribution of bacteria from both natural and anthropogenic sources. This objective is met through bacterial source tracking monitoring. In this subsection current methods for identifying locations which contribute high concentrations of bacteria to surface waters and for distinguishing between human and non-human bacterial sources are described. This section is not intended to be a comprehensive, detailed literature review of current methods available. A more thorough review is included in Appendix B.

Bacterial source tracking may be organized into two broad approaches:

1.) pinpointing the location of the bacteria source; and
2.) identifying the types of bacteria sources contributing to the problem

Locating bacterial sources

One of the most economical methods of identifying sources is to conduct intensive upstream-downstream water quality monitoring to identify specific stream reaches, land uses, or tributaries that are a problem. This type of monitoring, coupled with good field observation and land use information, can be used to identify sources contributing to the problem.

Information on land use can be used to select monitoring sites that bracket potential bacterial sources. Bacterial monitoring sites can be placed upstream and downstream of the potential source. Statistical methods such as the paired t-test can be used to determine if there is a significant difference in bacterial levels between sites. Because of the variability inherent in bacterial testing, numerous sampling events may be necessary. Monitoring should be targeted to the season or time when pollution is most likely to occur.

Determining the types of sources through bacterial source tracking techniques

Most bacterial source tracking techniques are still in the experimental stage and are often quite costly. It is important to pick the appropriate time to use source identification and then pick the appropriate method. It is also important to recognize that these techniques do not necessarily determine how much each source contributes to bacterial contamination, only the different kinds of sources. In addition, it is possible that not all

source types will be identified or, with some techniques, that sources may actually be misidentified.

Listed below are some of the more common bacterial source tracking techniques:

Species-specific indicators: There are a number of bacterial strains that are specific to certain animals. These indicators can be used to determine if bacteria pollution from specific species is present.

Antibiotic resistance analysis: Humans and animals are exposed to different drugs throughout their lives, so bacteria from animals may not be resistant to drugs that bacteria from humans are resistant to. These resistance patterns can be used to differentiate between human and animal sources.

Chemical indicators: Chemical indicators are natural by-products of human metabolism or activity. Specific chemicals can be used as tracers to indicate sources or routes of contamination. Examples include testing for the presence of caffeine or optical brighteners (found in laundry detergents) to determine if human sources are present.

DNA typing: DNA typing is one of the source identification techniques available. Some bacteria uniquely adapt to the gut of the host species. Once they are identified in the host, they can also be identified in the water. The procedure involves creating a "library" of known DNA types, including collecting feces from known species in the watershed. The DNA patterns from bacteria in the water are then compared to DNA patterns in the library.

Many universities, states and local governments are still evaluating the accuracy and usefulness of the DNA typing methods. When sources are obvious, actions can be taken right away to reduce pollutant loading without extensive use of DNA testing. Also, methods of bacteria tracking vary, and there has only recently been an objective evaluation of the different methods and the pros, cons, and accuracy of each (Stewart et. al., 2003).

There is no easy, low-cost method for differentiating between human and non-human sources of fecal bacterial contamination. Accurately quantifying the contribution from each source is still not possible. The best approach for an investigator at this time is to consider the land uses and sources under investigation, and tailor the method or methods to fit the situation. At times, a combination of methods is appropriate for discerning sources.

Some considerations in choosing a method or methods are:

- Type of sources (human, non-human, sewage, on-site, domestic, or feral animal);
- Pollutant loading mechanism and time frame;
- Budget.

For example, if human fecal contamination is suspected one might test for presence of bacterial or phage strains more specific to humans. The most frequently used and well-tested method at this time is DNA typing. Promising methods on the horizon include techniques using Polymerase Chain Reaction technology, multiple antibiotic resistance, and bacteriophages, as well as methods using a combination of indicators. Because of the recent focus on nonpoint pollution, there is great deal of research being done on possible methods to determine the sources of fecal bacterial pollution. As this document is being written, many promising studies examining alternative methods are being conducted.

3.4 Overview of Best Management Practices Useful in Controlling Bacteria

The primary objective of the Pathogen Work Plan is identifying, developing, and implementing BMPs to address controllable sources of bacteria. BMPs are defined as any program, technology, process, siting criteria, operating method, measure or device which controls prevents, removes, or reduces pollution. For instance;

- Pollution Prevention or Source Control BMPs – are operational practices that prevent pollution by reducing potential pollutants at the source. They typically do not require construction.

- Treatment Control BMPs – are methods of treatment to remove pollutants from storm water.

A listing of BMPs useful for controlling bacteria in urban environments is given below. The list is based on the California BMP Handbooks (CASQA, 2000) and the City Stormwater Quality Control Criteria Plan (LWA, 2003).

POLLUTION PREVENTION BMPs

Source Reduction Practices
Animal Waste Collection
Debris Removal
Education Programs
Exposure Reduction
Landscaping and Lawn Maintenance Controls
Parking Lot and Street Cleaning Operations
Wildlife and Waterfowl Management

Land Use Management Practices
Buffers, Easements, Etc.
Sanitary Waste Management
Dedicated "Dog Parks"

Boating and Marine Practices
Boat Operations
Liquid Waste and Fuel Handling
Sewage Disposal
Solid Waste Generation and Disposal

TREATMENT CONTROL BMPs

- Vegetated Swales
- Extended Detention Basins
- Wet Ponds
- Constructed Wetlands
- Detention Basin/Sand Filter
- Infiltration Basin/Trenches
- Media Filter
- Retention Irrigation

Each of the above BMPs is unique in its ability to control bacteria.

4.0 PATHOGEN PLAN

The Pathogen Plan described in this section follows a prescribed sequence of events, by which bacterial sources are identified and mitigated. The plan mandates an iterative approach consisting of five sequential steps. These include:

- Characterization Monitoring – The targeted waterbodies and discrete areas within those waterbodies are monitored for bacteria for a period of one year.

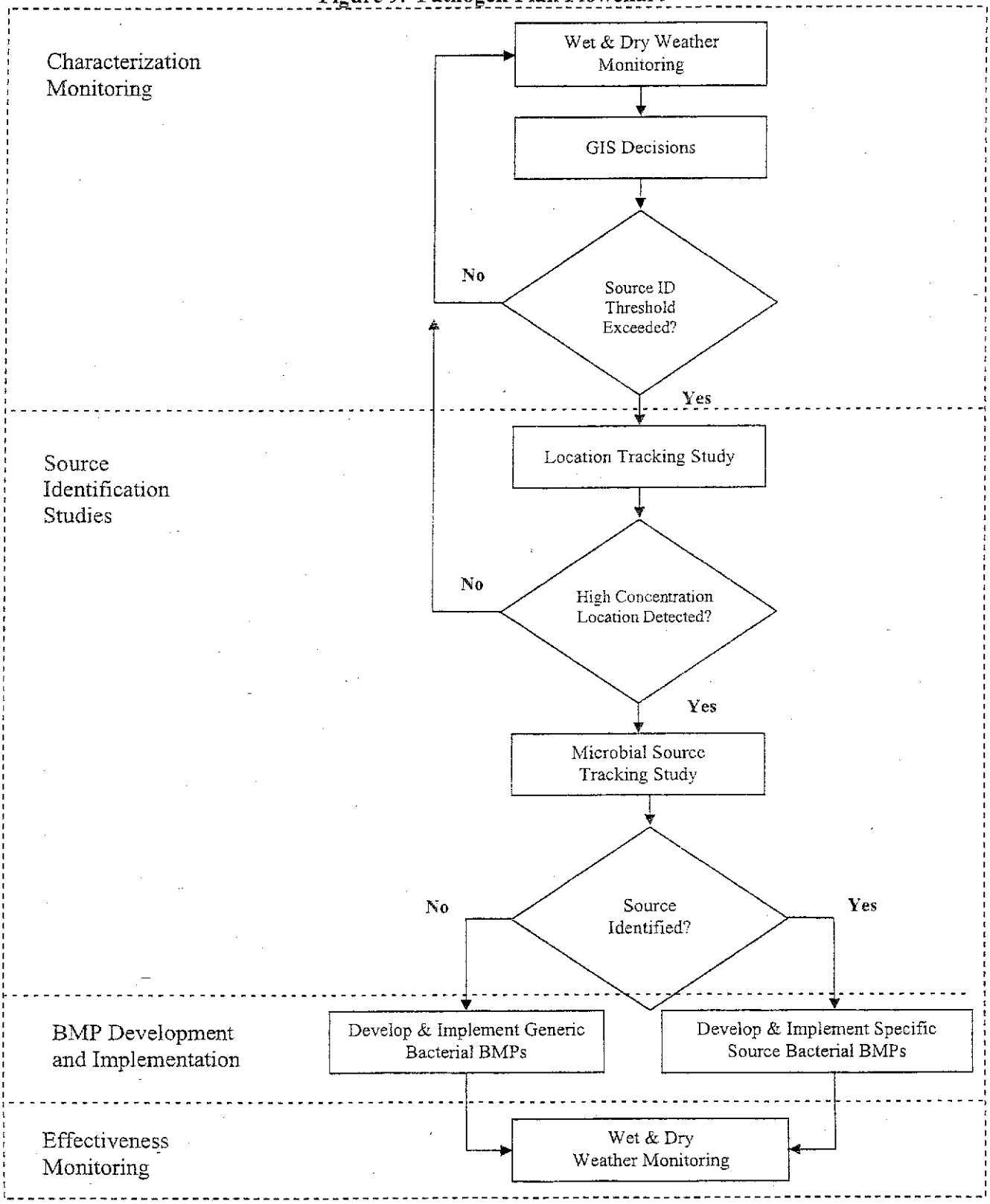
- Source Identification Studies – "Problem" areas or sites within a waterbody identified in the Characterization Monitoring step are examined at a more detailed level. This will be accomplished by using DNA technology and Geographic Information System (GIS) tools to "pinpoint" and identify bacteria sources.

- BMP Development and Implementation – Appropriate BMPs (including policies, outreach programs, etc) are identified and implemented in areas identified as being problematic.

- Effectiveness Monitoring and Plan Assessment – Waterbodies are monitored to determine whether BMPs implemented are effectively preventing bacteria from entering the waterbody. The overall progress and effectiveness of the efforts to address bacterial pollution are reviewed.

These steps are shown in Figure 9. All steps are described in greater detail below.

Figure 9. Pathogen Plan Flowchart



4.1 Characterization Monitoring

Bacteria monitoring will be conducted at strategic locations within the drainages of the impaired waterbodies. This monitoring will help determine long-term trends in bacteria loading as well as short-term variations in bacteria concentrations.

Wet Weather (i.e. Storm) Monitoring

Wet weather samples will be collected during a targeted storm event, defined as a storm that produces at least 0.25 inches of precipitation. All wet weather monitoring will consist of grab samples. Discharge samples should be taken directly from the discharge stream if possible. Wet well and receiving water samples should be taken from just below the surface of the water. Sufficient precipitation is needed to produce runoff, mobilize bacteria, and increase stream flow. Wet weather monitoring should be coordinated, if possible, with other ongoing water quality monitoring programs. Receiving water monitoring should be undertaken from a safe vantage point that permits sampling as close to the middle of the water body as possible (e.g. samples may be collected by lowering collection containers from bridges, collected with a sampling pole from the bank, etc.). When a discharge into a receiving water is occurring, the discharge should be sampled. When no discharge is occurring, the wet well of the sampling site should be sampled. This may require coordination with municipal staff. In some cases, discharge samples must be collected by municipal employees due to access issues (e.g. the sampling location is within a pump station, etc.). Specific wet weather sampling criteria are:

- Receiving Water Monitoring: One sample per site, per storm.
- Discharge or Wet Well Monitoring: One sample per site, per storm.
- Attempts will be made to monitor five storms per year (including the "first flush", if possible).
- These will include at least one storm each in
  - Fall (Sept. 16 to Nov. 30)
  - Winter (Dec. 1 to Feb. 15)
  - Spring (Feb. 16 to April 20)
- During each storm at least one sample will be collected at each site.
- Samples will be collected with a minimum of at least three weeks between storm events.
- Wet weather monitoring will only take place after a dry period, defined as a continuous three day period with no measurable precipitation.

Dry Weather Monitoring

Dry weather samples will be collected on a regular basis. All dry weather monitoring will consist of grab samples. Discharge samples should be taken directly from the discharge stream if possible. Wet well and receiving water samples should be taken from just below the surface of the water. Sampling will take place the first and third Tuesdays of every month, unless it can be easily coordinated with other ongoing water quality sampling. Should measurable precipitation occur in the seven days prior to a scheduled dry weather monitoring event, the event will be rescheduled to allow for at least seven days without measurable precipitation prior to sampling. Dry weather monitoring should be coordinated, if possible, with other ongoing water quality monitoring programs. Receiving water monitoring should be undertaken from a safe vantage point that permits sampling as close to the middle of the water body as possible (e.g. samples may be collected by lowering collection containers from bridges, collected with a sampling pole from the bank, etc.). When a discharge into a receiving water is occurring, the discharge should be sampled. When no discharge is occurring, the wet well of the sampling site should be sampled. This may require coordination with municipal staff. In some cases, discharge samples must be collected by municipal employees due to access issues (e.g. the sampling location is within a pump station, etc.).

- Receiving Water Monitoring: One sample per site, twice a month.
- Discharge or Wet Well Monitoring: One sample per site, twice a month.

Monitoring Overview

The number and location of monitoring sites is presented in greater detail in the Monitoring Plan (Appendix A). However, as monitoring data is collected and analyzed, it may become necessary to move and/or introduce additional sampling locations. In addition, alternative sampling locations may be warranted to meet specific needs associated with any compliance monitoring or source identification studies that may be required.

Some sample collection duties associated with the Characterization and Effectiveness Monitoring may be undertaken by properly trained volunteers. This approach has the benefits of optimizing the Permittee's resources and encouraging stakeholder involvement. However, liability and safety issues must be fully considered before allowing volunteer stakeholder organizations to undertake any sampling duties.

Data from this component of the monitoring plan will be fed into a GIS-based Decision Support Tool that will assist the permittees in determining the spatial and temporal variations in bacteria concentrations. The information generated by the GIS Decision Support Tool is then used to identify locations or sub-drainages that generate and contribute high concentrations of bacteria to the waterbodies of concern.

The final element of the Characterization Monitoring component consists of determining whether a site is sufficiently impacted by bacteria to warrant the implementation of a Source Identification Study. Any site within a waterbody being examined should be a

candidate for Source Identification Studies if Characterization Monitoring results show that it consistently exceeds bacteria criteria.

4.2 Source Identification Studies

The source identification investigations will utilize two approaches:

Location Tracking Studies - Fecal indicator bacteria sampling will be used to identify spatial patterns of bacterial contamination. Permittee staff will collect bacteria samples from outfall discharges that enter the receiving waters, traveling upstream, taking successive samples from succeeding trunk lines to the storm drains. These "geo-spatial" data should provide valuable insight into the location of the bacterial source and migration patterns of indicator bacteria that are causing exceedances of standards. Water samples will be tested for total coliforms and *E. coli* as described in Standard Methods for the Examination of Water and Wastewater, 20th edition.

Microbial Source Tracking (MST) Studies - Analytical methods will be used to evaluate the organisms (human or non-human) from which the indicator bacteria likely originated. The MST method being used in this study will be the species-specific technique using *Bacteroides-Prevotella* 16S rRNA Polymerase Chain Reaction (PCR)/ Terminal Restriction Fragment Length Polymorphism (TRFLP).

TRFLP is one of the most reliable and established methods for determining the sequence information of the 16s rRNA genes. Organisms are detected using a combination of PCR of a gene sequence and TRFLP. The *Bacteroides-Prevotella* (B-P) method uses genus specific primer sets to discriminate between human and "other" unidentified sources of B-P strains. In lay terms, this technique is able to distinguish between bacteria from humans, dogs, cats, birds, etc. This knowledge then allows appropriate BMPs to be selected for a given bacteria source.

Short-term location tracking studies, by necessity, must be individualized to suit the specific requirements of a given geographic situation and will be designed by Permittee staff and/or consultants to characterize possible sources of bacterial contamination at impaired waterbodies. Because of the highly technical and analytical nature of this microbial source tracking technique, it will be necessary to contract out the sample collection and processing to professional laboratories and/or universities that are capable of undertaking this work.

Due to the high costs ($60 - $200/test) of MST testing, potential site locations of high bacteria concentrations will be prioritized using fecal indicator testing as much as possible during Location Tracking Studies.

4.3 BMP Development and Implementation

Once a site or activity that contributes high bacteria concentrations has been identified, BMPs must be identified and implemented to address the controllable sources of bacteria. Ideally, selection of BMPs should focus first on source control BMPs and second on treatment control BMPs. Typically, source control BMPs will serve to reduce bacteria from activities in the most cost effective manner. Treatment control BMPs should be considered when source control BMPs have been shown to be ineffective or when special environmental or site conditions warrant a more comprehensive approach.

In selecting and implementing a BMP (or BMPs) for the identified controllable source(s) of bacteria the following issues will be considered:

- How effective is the BMP in addressing the type of bacteria identified?
- Is the BMP consistent with current regulatory requirements?
- What are the maintenance requirements of the BMP?
- Does the BMP have wider application than just bacteria?
- Is the BMP acceptable to the community?
- Are the costs associated with the BMP commensurate with the environmental benefit?
- Can the BMP be applied area-wide or is it a site-specific application?
- Is the BMP supported by local ordinance or other appropriate means?

4.4 Effectiveness Monitoring and Plan Assessment

This monitoring will be closely aligned to the Characterization Monitoring effort described previously and will assist in assessing trends in bacteria concentration (see Appendix A). The location of effectiveness monitoring sites and the frequency of monitoring will be determined after BMPs have been implemented. The location of and sampling frequency of nearby Characterization Monitoring sites may be sufficient to determine BMP effectiveness, negating the need for new sites. Effectiveness monitoring data can also be fed into the GIS Decision Support Tool for comparison to other locations.

As noted previously the objectives of the Pathogen Plan are to (1) identify areas and /or activities which contribute high pathogen concentrations in stormwater; (2) develop and conduct a monitoring program for assessing the contribution of pathogens from natural and anthropogenic sources; and (3) develop and implement BMPs including policies and procedures for addressing controllable sources of bacteria.

The Plan as presented in the previous pages will provide insights and data to determine whether these objectives are met. Ultimately the Plan will be assessed as to whether it reduced the controllable sources of bacteria and in doing, improved the quality of the Stockton/San Joaquin County waterbodies. If the controllable sources are not a significant contributor of bacteria loading then the assessment of the Pathogen Plan will depend on indirect means of measuring program effectives, e.g. pet litter clean up citations, number of public education impressions, etc.

If controllable sources prove to be a significant contributor of the bacteria loading then a trend analysis of the monitoring data (both discharge characterization and receiving water) may be made. However, because of the intermittent and variable nature of urban runoff the trend analysis will likely require multiple years of monitoring data. This long term monitoring will be accomplished through the Discharge Characterization and Receiving Water portion of the City/County regular permit defined monitoring program.

Once an adequate data set has been generated, long term trend in stormwater quality may be identified by statistical tests of time series of early and late season event mean concentrations (EMCs), and/or annual mass load estimates or median annual EMCs. Appropriate statistical tests for identifying long-term trends in stormwater quality include regression, the Mann-Kendall test, Sens's test, the rank von Neumann test, and Box-Jenkins ARIMA models. The City and County at the end of the Phase 1 monitoring effort will reevaluate the advantages and disadvantages of these methods and recommend one for long-term trend analysis.

4.5 Stakeholder Participation and TMDL Interface

The purpose of this section is to describe the process that will be used to communicate with stakeholders, public entities, and regulatory agencies during the implementation of this pathogen plan.

The Permittees will work with the San Joaquin County Environmental Health Department and other interested stakeholders to identify the sources of pathogen loading and develop and implement BMPs to reduce discharges of pathogens. Efforts will be made to reach out to other interested parties to solicit input regarding all aspects of the proposed work plan. At least three meetings with interested stakeholders will take place during the period of this effort.

Additionally, the Permittees will work with the Regional Board and other agencies in the development of a TMDL for pathogen impaired waterbodies. The Permittees will participate in stakeholder forums and collaborative technical studies as necessary to assist the Regional Board in completing the TMDL.

4.6 Implementation Schedule

Due to the number of waterbodies being examined and the intensive nature of the work, the monitoring and analysis of these waterbodies will be staggered. The plan schedule is presented in Table 4. The schedule for Phase I monitoring and analysis is presented in Table 5.

Table 4. Schedule for Waterbody Monitoring and Analysis

Monitoring Phase	Waterbody	Start Date	End Date
Phase I	Smith Canal	July 1, 2004	June 30, 2007
	Mormon Slough		
Phase II	Mosher Slough	July 1, 2007	June 30, 2010
	Five Mile Slough		
Phase III	Lower Calaveras River	July 1, 2010	June 30, 2013
	Walker Slough		

Table 5. Schedule for Phase I Monitoring and Analysis

Monitoring Type	2004	2005	2006	2007
	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND
Characterization				
Source ID Studies				
Effectiveness				

At the completion of Phase I the Permittees will reassess this work plan to determine whether Phases II and III are necessary. As part of this assessment the Permittees will confer with the Regional Board and other stakeholders. It is possible that successful identification of source bacteria and implementation of effective BMPs that subsequent monitoring efforts will not be warranted.

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City of Stockton
San Joaquin County
Monitoring Plan for Support of the Pathogen Plan

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APPENDIX A

Monitoring Plan

APPENDICES

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1.0 OBJECTIVE

The primary objectives of this Pathogen Monitoring Plan are to (1) identify the timing, extent, and magnitude of bacterial concentrations in six 303(d) listed waterbodies within the City of Stockton (City) by collecting dry and wet weather discharge and receiving water data, and (2) identifying the specific sources of bacterial pollution.

2.0 SCOPE OF THE MONITORING PLAN

The first objective of the Pathogen Monitoring Plan is to determine the relative contribution of urban stormwater runoff and dry weather discharges to bacteria levels in waterways identified as impaired (i.e. included on the 303(d) list). This will be fulfilled by monitoring trends in the levels of bacteria in six 303(d) listed waters within the urbanized area, including Mosher Slough, Five Mile Slough, Lower Calaveras River, Smith Canal, Mormon Slough, and Walker Slough, measuring bacteria concentrations in storm drain discharges (during both wet and dry weather periods). The second objective is identifying specific sources of bacteria. This will be accomplished by undertaking a source tracking/source identification effort to identify sites and/or activities that produce high concentrations of bacteria.

The specific elements of this plan are outlined below:

- Evaluate dry-weather contributions to bacteria loads in urban runoff and receiving waters;
- Evaluate wet-weather contributions to bacteria loads in urban runoff and receiving waters;
- Evaluate the relative contributions of bacteria in urban runoff and contributions from areas upstream from urban runoff;
- Evaluate relative contribution of bacteria from sub-drainages within the watersheds of impaired waterbodies;
- Identify the sources and/or activities that contribute high concentrations of bacteria to receiving waters;
- Assess the effectiveness of any best management practices (BMPs) that may be implemented as a result of successful source tracking activities; and
- Provide data to better allocate monitoring resources for future monitoring.

To identify sites and/or activities contributing to the load of bacteria to the environment, monitoring will, by necessity, take a multi-lateral approach measuring the concentrations of bacteria in dry and wet weather urban discharge and receiving waters.

3.0 MONITORING APPROACH

The pathogen monitoring program consists of three general monitoring components:

- **Characterization Monitoring**: What are the bacterial conditions and trends over time?

- **Source Identification Studies**: Where are the bacteria coming from?
- **Effectiveness Monitoring**: Is the implementation of BMPs improving water quality?

These three programs are closely linked, with the Characterization Monitoring intended to provide data for directing any needed Source Identification Studies. The results of the source identification efforts will indicate which types of BMPs should be implemented to control or mitigate sources of high bacteria concentrations. Effectiveness Monitoring will then be employed to determine the effectiveness of any BMPs implemented. A flowchart of monitoring sequences is presented in Figure 1.

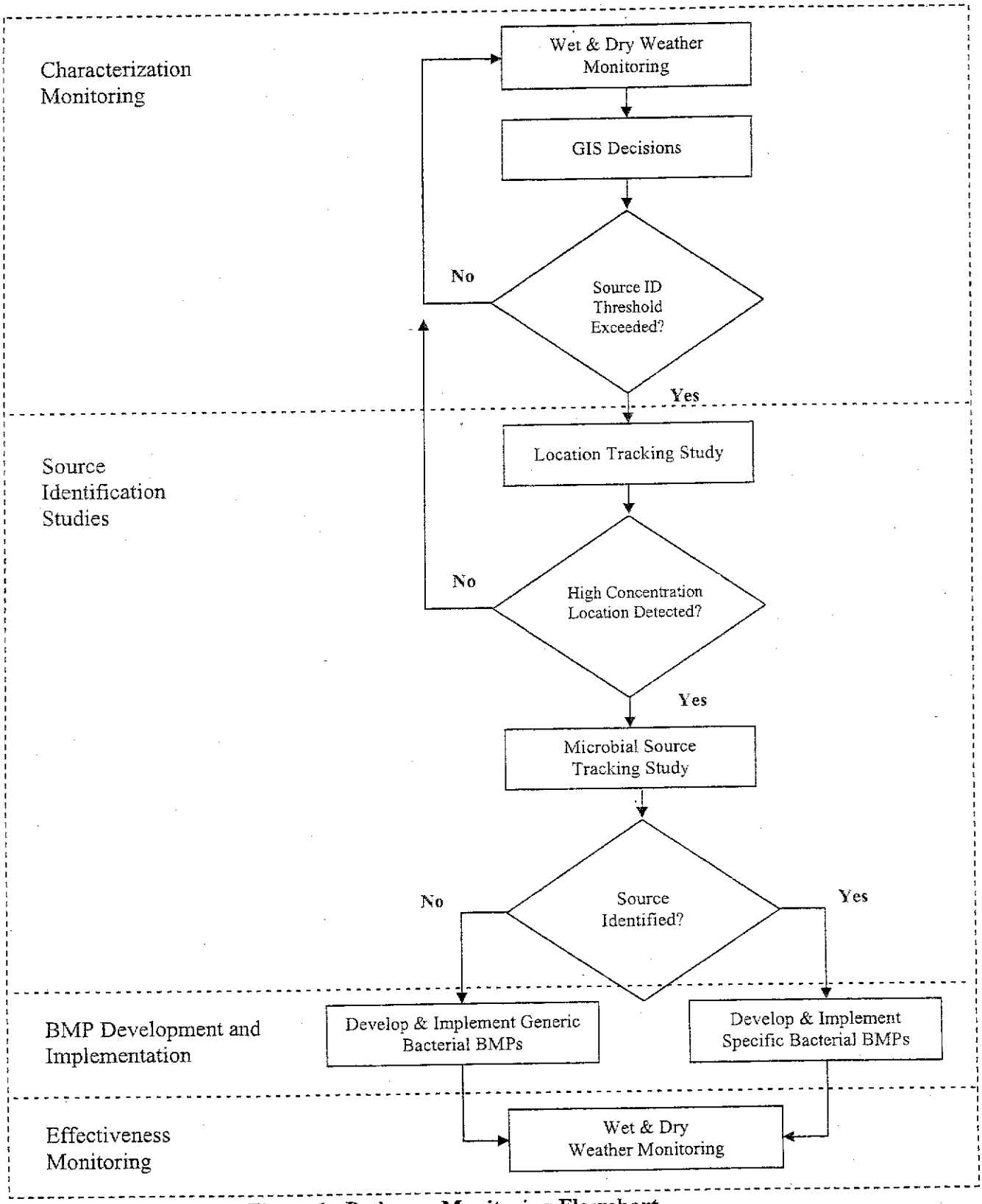

Figure 1. Pathogen Monitoring Flowchart

Details of the three monitoring components are provided below.

3.1 Characterization Monitoring

Bacteria monitoring will be conducted at strategic locations within the drainages of the impaired waterbodies. This monitoring will help determine long-term trends in bacteria loading as well as short-term variations in bacteria concentrations in relation to water quality standards.

The number and location of monitoring sites is presented below. However, as monitoring data is collected and analyzed, it may become necessary to move and/or introduce additional sampling locations. In addition, alternative sampling locations may be warranted to meet specific needs associated with any compliance monitoring or source identification studies that may be required.

Some sample collection duties associated with the Characterization and Effectiveness Monitoring may be undertaken by properly trained volunteers. This approach has the benefits of optimizing the Permittee's resources and encouraging stakeholder involvement. However, liability and safety issues must be fully considered before allowing volunteer stakeholder organizations to undertake any sampling duties.

Data from this component of the monitoring plan will be fed into a GIS-based Decision Support Tool that will assist the Permittees in determining the spatial and temporal variations in bacteria concentrations. The information generated by the GIS Decision Support Tool is then used to identify locations or sub-drainages that generate and contribute high concentrations of bacteria to the waterbodies of concern. Once these sub-drainages have been identified, Source Identification Studies may be undertaken which pin-point bacteria sources.

The GIS software (ArcExplorer) is able to display, query and retrieve pathogen data, and is available free of charge from the manufacturer (the Environmental Systems Research Institute or "ESRI"). ArcExplorer supports a wide variety of standard data sources, and can be used on its own with local data sets or as a client to Internet data and map servers. ArcExplorer's user interface is simple to use, and includes an intuitive menu and tool bars. With these, one can add themes from existing data sources, control theme characteristics, print maps, zoom in/out, pan, and identify map features. In addition, one can pan and zoom through multiple map layers and identify, locate, and query geographic and attribute data. ArcExplorer's symbolization tools can be used to create maps based on attributes contained in the database, and perform basic statistical analyses on the geographic data.

The final element of the Characterization Monitoring component consists of determining whether a site is sufficiently impacted by bacteria to warrant the implementation of a Source Identification Study. Any site within a waterbody being examined should be a candidate for Source Identification Studies if Characterization Monitoring results show that it consistently exceeds bacteria criteria and/or maintains high geometric means of bacteria concentrations relative to other sites within the waterbody.

3.2 Source Identification Studies

Specific objectives of the source identification studies component include the following:

- Utilize characterization monitoring and short-term "special studies" bacteria data to determine the spatial source and magnitude of indicator bacteria, including patterns and trends to the extent possible.

- Utilize Microbial Source Tracking (MST) analytical techniques to determine the species (e.g., birds, humans, etc.) generating the indicator bacteria, to the extent possible.

Once Characterization Monitoring indicates that an established Characterization monitoring site may be receiving high bacteria loads from a bacteria source, a series of short-term bacterial monitoring studies will be conducted by the Permittees to identify the specific source(s) of bacterial contamination. These studies will focus on fecal indicator testing and MST methods. Permittee staff will collect samples from within the drainage that enter into the receiving waters, traveling upstream with successive samples.

The source identification investigations will utilize two approaches:

Location Tracking Studies - Fecal indicator bacteria sampling will be used to identify spatial patterns of bacterial contamination. Permittee staff will collect bacteria samples from outfall discharges that enter into the receiving waters, traveling upstream, taking successive samples from succeeding trunk lines to the storm drains. These "geo-spatial" data should provide valuable insight into the location of the bacterial source and migration patterns of indicator bacteria that are causing exceedances of standards. Water will be tested for total coliforms and *E. coli* as described in Standard Methods for the Examination of Water and Wastewater, 20th edition.

Microbial Source Tracking (MST) Studies - Analytical methods will be used to evaluate the organisms (human or non-human) from which the indicator bacteria likely originated. The MST method being used in this study will be the species-specific technique using *Bacteroides-Prevotella* 16S rRNA Polymerase Chain Reaction (PCR)/ Terminal Restriction Fragment Length Polymorphism (TRFLP).

TRFLP is one of the most reliable and established methods for determining the sequence information of the 16s rRNA genes. Organisms are detected using a combination of PCR of a gene sequence and TRFLP. The *Bacteroides-Prevotella* (B-P) method uses genus specific primer sets to discriminate between human and "other" unidentified sources of B-P strains.

Short-term location tracking studies, by necessity, must be individualized to suit the specific requirements of a given geographic situation and will be designed to characterize possible sources of bacterial contamination at impaired waterbodies. Because the highly technical and analytical nature of this microbial source tracking technique, it will be necessary to contract out the sample collection and processing to professional laboratories and/or universities that are capable of undertaking this work.

Due to the high costs ($60 - $200/sample) of MST testing, potential site locations of high bacteria concentrations will be prioritized using fecal indicator testing as much as possible during Location Tracking Studies.

These results of MST efforts will be used to help identify BMPs that are most likely to mitigate the sources identified.

3.3 Effectiveness Monitoring

This monitoring will be closely aligned to the Characterization Monitoring effort and assist in assessing BMPs effectiveness. The location of effectiveness monitoring sites and the frequency of monitoring will be determined after BMPs have been implemented. The location of and sampling frequency of nearby Characterization Monitoring sites may be sufficient to determine BMP effectiveness, negating the need for new sites. Effectiveness monitoring data can also be fed into the GIS Decision Support Tool for comparison to other locations.

4.0 PROGRAM IMPLEMENTATION SCHEDULE

Due to the number of waterbodies being examined and the intensive nature of the work, the monitoring and analysis of these waterbodies will be staggered. Each of the three general monitoring components is expected to take approximately one year to complete, or a total of three years for each waterbody. The program schedule is presented in Table 1. The schedule for Phase I monitoring and analysis is presented in Table 2.

Table 1. Schedule for Waterbody Monitoring and Analysis

Monitoring Phase	Waterbody	Start Date	End Date
Phase I	Smith Canal	July 1, 2004	June 30, 2007
	Mormon Slough		
Phase II	Mosher Slough	July 1, 2007	June 30, 2010
	Five Mile Slough		
Phase III	Lower Calaveras River	July 1, 2010	June 30, 2013
	Walker Slough		

Table 2. Schedule for Phase I Monitoring and Analysis

Monitoring Type	2004	2005	2006	2007
	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND
Characterization				
Source ID Studies				
Effectiveness				

5.0 MONITORING STATIONS

Brief descriptions of the sites selected for monitoring are described below. A summary of the study monitoring sites and the samples that will be collected from each location are listed by program phase. The pathogen impaired waterbodies are shown in Figure 2.

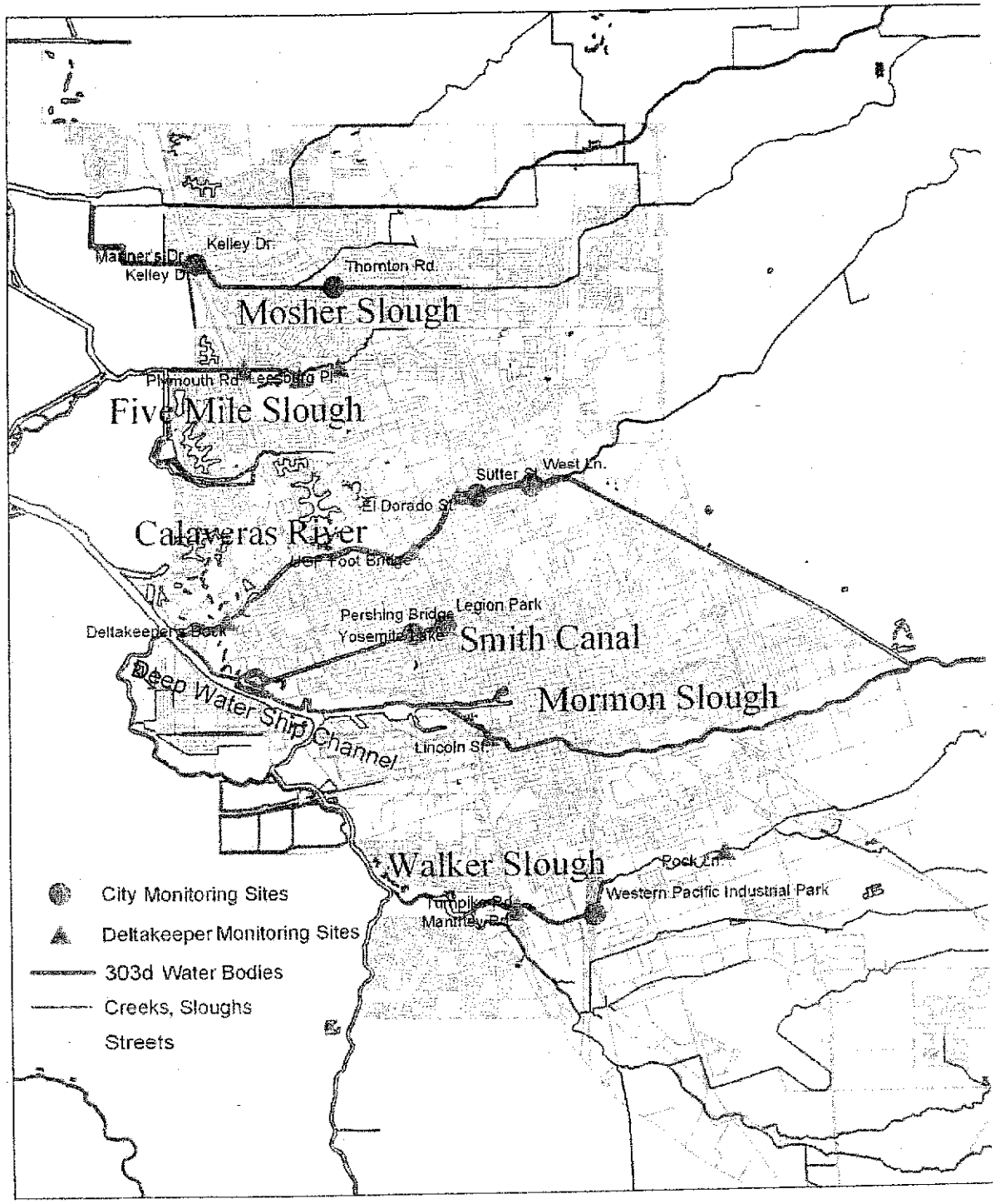

Figure 2. Pathogen Impaired Waterbodies within the Stockton Urbanized Area.

5.1 Phase I Monitoring Sites (2004-2007)

SMITH CANAL
The entire length of the Smith Canal is 303(d) listed for bacteria. Four monitoring sites are located on the Smith Canal. The most upstream site, Yosemite Lake, will allow quantification of bacteria loads in the canal at its origin (Legion Park). The downstream sites will allow quantification of bacteria loads as the river traverses the urbanized area. Site descriptions are presented in Appendix 1. If possible, pathogen monitoring will be integrated with the Smith Canal Water Quality Monitoring Program.

MORMON SLOUGH
Mormon Slough is 303(d) listed for bacteria from the confluence with the Stockton Diverting Canal to the confluence with the Deep Water Channel. The slough is frequented by homeless people. Four monitoring sites are located on Mormon Slough. Site descriptions are presented in Appendix 1.

Phase I site locations and monitoring information are presented in Figure 3 and Table 3.

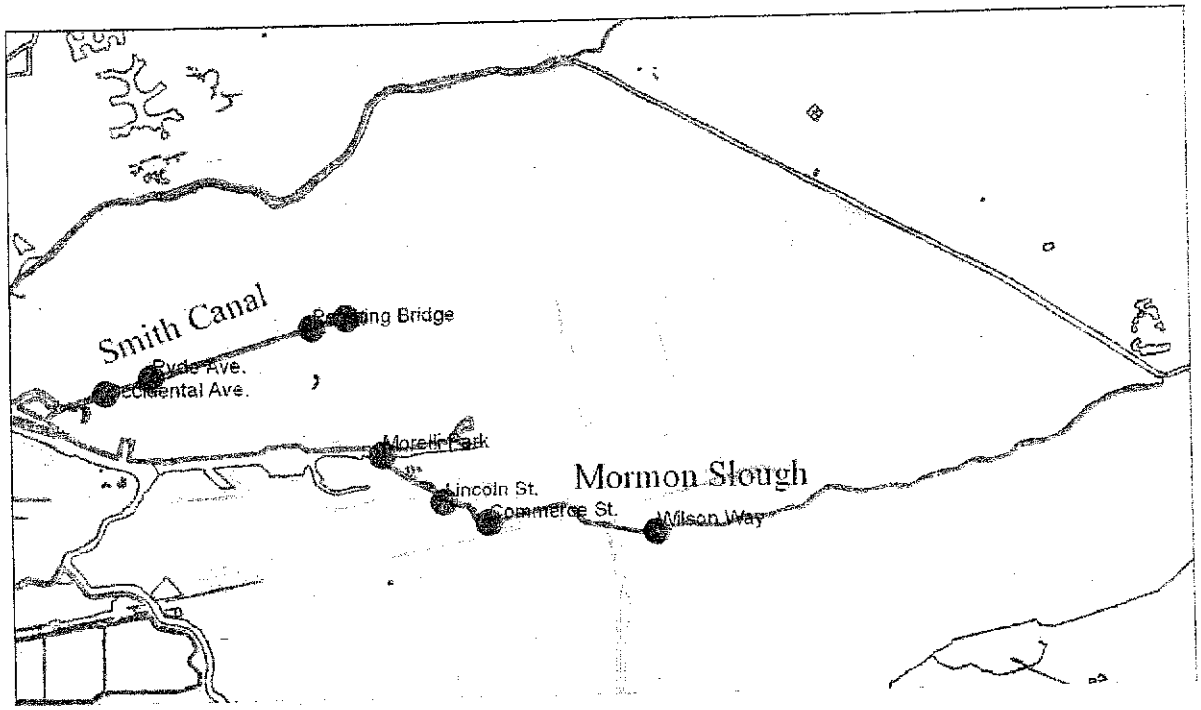

Figure 3: Tentative Phase I sampling locations.

Table 3: Phase I: Tentative Sampling Sites and Sample Phase Collected by Site.

Waterbody and Monitoring Location	Bacteria Monitoring Sites	
	Discharge Site ID	Receiving Water Site ID
Smith Canal		
Occidental Ave.	SC4-D	SC4-R
Ryde Ave.	SC3-D	SC3-R
Pershing Ave. Bridge	SC2-D	SC2-R
Yosemite Street/Legion Park	SC1-D	SC1-R
Mormon Slough		
Turning Basin (Morelli Park)	MR4-D	MR4-R
Lincoln Street	MR3-D	MR3-R
Commerce Street	MR2-D	MR2-R
Wilson Way	MR1-D	MR1-R

5.2 Phase II Monitoring Sites (2007-2010)

MOSHER SLOUGH

Only the section of Mosher Slough from Mosher Creek to the confluence with Bear Creek is 303(d) listed for bacteria. The number and location of characterization monitoring sites will be determined prior to the initiation of the Phase II monitoring. Tentatively, at least four monitoring sites will located in Mosher Slough. The most upstream site will allow quantification of bacteria loads in the slough as it flows through the urbanized area. The downstream sites will allow quantification of bacteria loads as the slough traverses the urbanized area.

FIVE-MILE SLOUGH

The reach of Five-Mile Slough between Alexandria Place and confluence with Fourteen Mile Slough is 303(d) listed for bacteria. The number and location of characterization monitoring sites will be determined prior to the initiation of the Phase II monitoring. Tentatively, at least three monitoring sites are located in Mosher Slough. This will allow quantification of bacteria loads in the slough as flows through the urbanized area. The downstream sites will allow quantification of bacteria loads as the slough traverses the urbanized area.

Phase II site locations and monitoring information are presented in Figure 4 and Table 4.

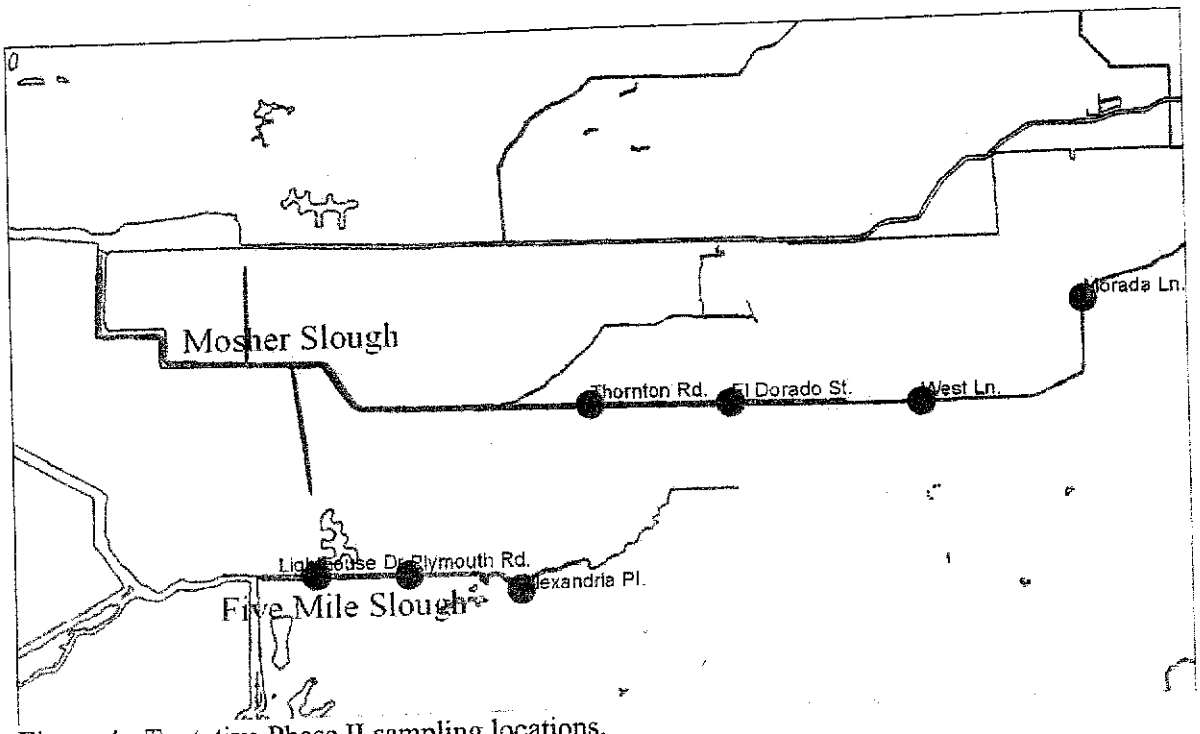

Figure 4: Tentative Phase II sampling locations.

Table 4: Phase II: Tentative Sampling Sites and Sample Phase Collected by Site.

Waterbody and Monitoring Location	Bacteria Monitoring Sites	
	Discharge Site ID	Receiving Water Site ID
Mosher Slough		
Thornton Rd.	MS4-D	MS4-R
El Dorado St.	MS3-D	MS3-R
West Ln.	MS2-D	MS2-R
Morada Ln.	MS1-D	MS1-R
Five-Mile Slough		
Lighthouse Dr.	FM3-D	FM3-R
Plymouth Rd.	FM2-D	FM2-R
Alexandria Pl.	FM1-D	FM1-R

5.3 Phase III Monitoring Sites (2010-2013)

CALAVERAS RIVER

The lower 5 miles of the Calaveras River (that portion which flows through urbanized Stockton) is listed for bacteria. The number and location of characterization monitoring sites will be

determined prior to the initiation of the Phase III monitoring. To allow evaluation of the contribution of urban runoff to bacteria concentrations, at least four sites are to be located on the Calaveras River. The most upstream site will allow quantification of bacteria loads in the river as river flows through the urbanized area. The downstream sites will allow quantification of bacteria loads as the river traverses the urbanized area.

WALKER SLOUGH

The entire length of Walker Slough is 303(d) listed for bacteria. The number and location of characterization monitoring sites will be determined prior to the initiation of the Phase III monitoring. Tentatively, at least three monitoring sites are located on Walker Slough. The most upstream site, Western Pacific Industrial Park, will allow quantification of bacteria loads in the slough as it flows through the urbanized area. The downstream sites will allow quantification of bacteria loads as the river traverses the urbanized area.

Phase III site locations and monitoring information are presented in Figure 5 and Table 5.

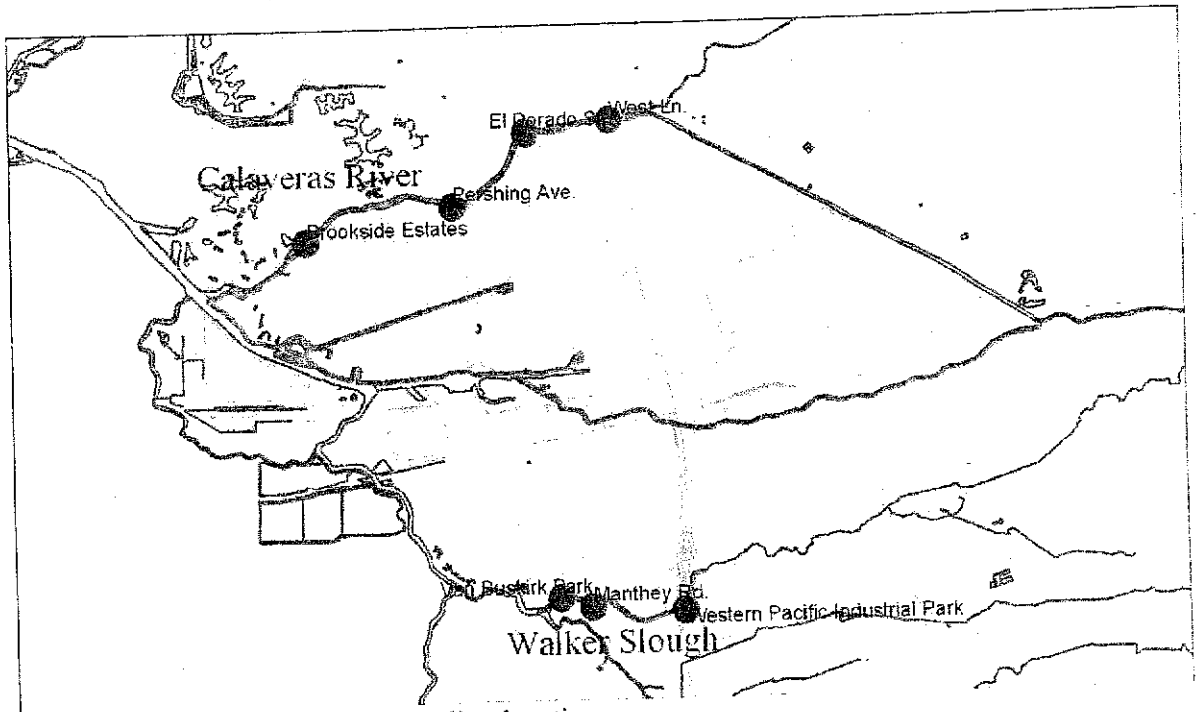

Figure 5: Tentative Phase III sampling locations.

Table 5: Phase III: Tentative Sampling Sites and Sample Phase Collected by Site.

Waterbody and Monitoring Location	Bacteria Monitoring Sites	
	Discharge Site ID	Receiving Water Site ID
Lower Calaveras River		
Brookside Estates	CR4-D	CR4-R
Pershing Ave.	CR3-D	CR3-R
El Dorado St.	CR2-D	CR2-R
West Ln.	CR1-D	CR1-R
Walker Slough		
Van Buskirk Park	WS3-D	WS3-R
Manthey Rd.	WS2-D	WS2-R
Western Pacific Industrial Park	WS1-D	WS1-R

6.0 MONITORING SCHEDULE

Bacteria monitoring will be coordinated with any other water quality monitoring programs being undertaken by the City.

6.1 Characterization Monitoring

Characterization Monitoring will be carried out in targeted waterbodies on a regular basis.

6.1.1 Wet Weather (i.e. Storm) Monitoring

Wet weather samples will be collected during a targeted storm event, defined as a storm that produces at least 0.25 inches of precipitation. All wet weather monitoring will consist of grab samples. Discharge samples should be taken directly from the discharge stream if possible. Wet well and receiving water samples should be taken from just below the surface of the water. Sufficient precipitation is needed to produce runoff, mobilize bacteria, and increase stream flow. Wet weather monitoring should be coordinated, if possible, with other ongoing water quality monitoring programs. Receiving water monitoring should be undertaken from a safe vantage point that permits sampling as close to the middle of the water body as possible (e.g. samples may be collected by lowering collection containers from bridges, collected with a sampling pole from the bank, etc.). When a discharge into a receiving water is occurring, the discharge should be sampled. When no discharge is occurring, the wet well of the sampling site may be sampled. This may require coordination of municipal staff. In some cases, discharge samples must be collected by municipal employees due to access issues (e.g. the sampling location is within a pump station, etc.). Specific wet weather sampling criteria are:

- Receiving Water Monitoring: One sample per site, per storm.

- Discharge or Wet Well Monitoring: One sample per site, per storm.

- Attempts will be made to monitor five storms per year (including the "first flush", if possible).

- These will include at least one storm each in

  - Fall (Sept. 16 to Nov. 30)
  - Winter (Dec. 1 to Feb. 15)
  - Spring (Feb. 16 to April 20)

- During each storm at least one sample will be collected at each site.

- Samples will be collected with a minimum of at least three weeks between storm events.

- Wet weather monitoring will only take place after a dry period, defined as a continuous three day period with no measurable precipitation.

6.1.2 Dry Weather Monitoring

Dry weather samples will be collected on a regular basis. All dry weather monitoring will consist of grab samples. Discharge samples should be taken directly from the discharge stream if possible. Wet well and receiving water samples should be taken from just below the surface of the water. Sampling will take place the first and third Tuesdays of every month, unless it can be easily coordinated with other ongoing water quality sampling. Should measurable precipitation occur in the seven days prior to a scheduled dry weather monitoring event, the event will be rescheduled to allow for at least seven days without measurable precipitation prior to sampling. Dry weather monitoring should be coordinated, if possible, with other ongoing water quality monitoring programs. Receiving water monitoring should be undertaken from a safe vantage point that permits sampling as close to the middle of the water body as possible (e.g. samples may be collected by lowering collection containers from bridges, collected with a sampling pole from the bank, etc.). When a discharge into a receiving water is occurring, the discharge should be sampled. When no discharge is occurring, the wet well of the sampling site should be sampled. This may require coordination with municipal staff. In some cases, discharge samples must be collected by municipal employees due to access issues (e.g. the sampling location is within a pump station, etc.).

- Receiving Water Monitoring: One sample per site, twice a month.

- Discharge or Wet Well Monitoring: One sample per site, twice a month.

6.2 Source Identification Studies

Source Identification Studies (i.e. Location Tracking Studies and Microbial Source Tracking) will be carried out in targeted geographical areas on as-needed basis, based upon results derived

from Characterization Monitoring. The need for, and location of such studies is dependent upon the analysis of data collected during the Characterization Monitoring.

As described previously, Location Tracking Studies using microbial indicators (total coliform, fecal coliform, and *E. coli*) arising from drainage outfalls and storm drains will be carried out in conjunction with conventional PCR analysis of *Bacteroides-Prevotella* to identify specific bacteria sources. The field of Microbial Source Tracking is constantly evolving. The methods described below may need to be updated by the time Source Identification Studies are employed.

Collection and concentration of sample: Grab samples consisting of 100 liters of water will be collected in clean, rinsed, polypropylene carboys. Grab samples will be collected via pump and filtered *in situ*. The samples will be filtered through three stainless steel sieves (75, 53 and 38 μm) to remove solids. The turbidity, conductivity, and pH will measured and the sample adjusted to a pH of 7.0. A fraction of raw sample will analyzed for total and fecal coliforms and *E. coli* according to Standard Methods, 20th edition.

The water will be pumped using a peristaltic pump through a 50,000 MW (molecular weight) cutoff Microza hollow fiber filter unit at an input pressure of 15-20 psi. Permeate will be collected in a plastic carboy and the retentate re-circulated to the sample reservoir until the volume is reduced to the final hold up volume of the system.

In order to concentrate 100 liters of water down to approximately 100 milliliters (a 1,000-fold concentration), two systems will be used. Both utilize a 50,000 MW cutoff Microza filter (Pall Corp., East Hills, New York). The larger system concentrates the sample from 100 liters to approximately 2 liters. The retentate will then be filtered through the small system, which concentrated down to roughly 100 mL. A diagram of this system is presented in Figure 6. Resulting filtered samples will then be transported to the laboratory for analysis.

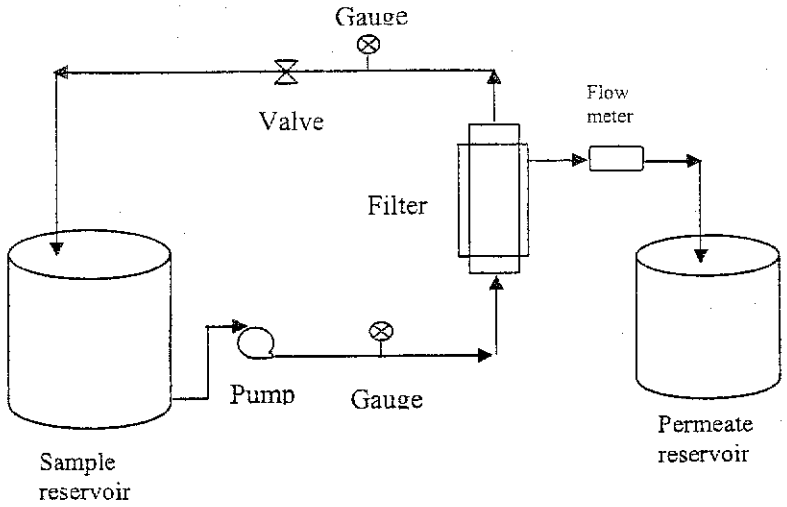

Figure 6. Diagram of MST Filtering System

6.3 Effectiveness Monitoring

Effectiveness Monitoring will be carried out in targeted waterbodies on a regular basis.

6.3.1 Wet Weather (i.e. Storm) Monitoring

Refer to section 6.1.1 for wet weather monitoring criteria

6.3.2 Dry Weather Monitoring

Refer to section 6.1.2 for wet weather monitoring criteria

7.0 PARAMETERS TO BE SAMPLED

Table 6. lists the specific constituents to be tested, analytical methods, expected detection limits, and holding times

Table 6. Constituents, Methods, Detection Limits, and Holding Times

Constituent	Analytical Method	Detection Limit	Holding Time
Bacteria			
E. coli	Colilert	10-24,196 MPN/100mL	6 hours
Total Coliform	MTF SM9221B MF SM9222B	20-1,600,000 MPN/100mL	6 hours
Fecal Coliform	MTFSM9221E MF SM 9222D	20-1,600,000 MPN/100mL	6 hours
Bacteroides-Prevotella	TBD	TBD	TBD

TBD: To be determined.

Analytical method and laboratory selection are fundamentally important steps in constructing a monitoring program. All analyses must meet data quality objectives, as stated in the method specified. The analytical method may change during the study if a different method is found to give better results (better QA/QC results and/or a more suitable detection limit).

8.0 MONITORING

Pathogen water quality monitoring procedures are presented in this section. In general, discharge and receiving water samples will be collected at each site.

8.1 Sampling Event Preparation

Sample event preparation includes preparation of field equipment, placing bottle orders, and contacting the necessary personnel regarding site access and schedule. The following steps should be completed two weeks prior to each sampling event:

1. Contact laboratories to order bottles and to coordinate sample transportation details.
2. Confirm scheduled sampling date with field crew, and set-up sampling day itinerary including sample drop-off.
3. Prepare equipment.
4. Prepare sample labels.
5. Prepare the sampling event summary and field log sheet to indicate the type of field measurements, field observations and samples to be taken at each of the stations.
6. Calibrate field measurement equipment.

Table 7 provides a field equipment checklist of equipment to mobilize prior to each sampling event.

Table 7. Field Equipment Checklist

✓	Monitoring Plan (this document)	✓	Coolers w/ Ice
✓	Sample Bottles w/ Pre-Printed and Extra Labels	✓	Powder-Free Gloves
✓	Event Summary Sheets	✓	Pens
✓	Field Log Forms	✓	First Aid Kit
✓	Chain of Custody Forms	✓	Cellular Telephone
✓	Watch	✓	Gate Keys (if necessary)
✓	Camera	✓	Paper Towels or Rags in a Box
✓	Tape Measure	✓	Plastic Trash Bags
✓	Hip Waders	✓	Distilled/DI Wash Bottles
✓	Distilled/DI Water for Blanks	✓	Grab Pole
✓	Sealable Plastic Bags	✓	Safety Equipment

8.1.1 Sampling Event Summary

A sampling event summary sheet will be produced for the sampling crew prior to each sampling event. Appendix 2 presents an example of a sampling event summary. The event summary sheet will outline sampling requirements at each sampling station, including a list of samples to be collected and QA/QC requirements. This summary will act as a guide to help field crews prepare for and track sample collection during each event.

8.1.2 Sample Bottle Order & Preparation

Sample bottle orders will be placed with the appropriate analytical laboratory two weeks prior to each sampling event. Bottles will be ordered for all samples, including quality control samples. Table 7 presents the proper bottle volume, immediate processing and storage needs. The field

crew must inventory sample bottles upon receipt from the laboratory to ensure that adequate bottles have been provided to meet analytical requirements for each sampling event.

8.1.3 Sample Bottle Labeling

All samples will be pre-labeled before each sampling event to the extent practicable. Pre-labeling sample bottles simplifies field activities, leaving only sample collection time, sample number, and the names of sampling personnel to be filled out in the field. Custom labels will be produced using blank water-proof labels. Using this approach will allow the stations and analytical constituent information to be entered into the computer program in advance, and printed as needed prior to each sampling event.

Labels shall be placed on the appropriate bottles in a dry environment; attempting to apply labels to sample bottles after filling will cause problems, as labels usually do not adhere to wet bottles. The labels shall be applied to the bottles rather than to the caps. Field labels shall contain the following information:

- Program Name
- Station ID
- Event Number
- Date
- Time
- Sampling Personnel
- Sample ID (see next section for ID conventions)
- Analytical Requirements
- Laboratory Conducting Analysis

8.1.4 Sample ID Conventions

Sample bottles submitted to laboratories for analysis shall be labeled with a sample ID devised as follows:

STATION- X-YY *example SC4-R-01*

Where: *STATION* = Station ID (i.e., SC4 = Smith Canal, station 4)
X = Sample Type (i.e., D = discharge, R = receiving water)
YY = Event number (i.e., 01, 02, 03,...)

For example, SC4-R-01 would be the sample ID for a sample collected at station SC4-R (Smith Canal station 4, receiving water sample) during the first sampling event.

8.2 Sample Collection

Table 8 lists specific constituents for which samples will be analyzed, sample volume required, and immediate processing and storage requirements.

Table 8. Sampling Requirements

Parameter	Sample Container	Sample Volume	Immediate Processing and Storage
Bacteria			
E. coli	Sterile Plastic	125 mL	Store at <4°C
Total Coliform Fecal Coliform	Sterile Plastic	125 mL	Store at <4°C

All samples will be grab samples

8.2.1 Clean Sampling Techniques

Samples will be collected using "clean sampling techniques" to minimize the possibility of sample contamination. For this program, clean techniques must be employed whenever handling bottles, lids, or intermediate containers. Clean sampling techniques are summarized below:

- Samples are collected only into new, clean, laboratory provided sample bottles.
- At least two persons, wearing clean powder-free nitrile gloves at all times, are required on a sampling crews.
- Clean, powder-free nitrile gloves are changed whenever something not known to be clean has been touched.
- For this program, clean techniques must be employed whenever handling grab sample or intermediate bottles.
- To reduce the potential for contamination, sample collection personnel must adhere to the following rules while collecting samples:
  1. No smoking.
  2. Never sample near a running vehicle. Do not park vehicles in immediate sample collection area, even non-running vehicles.
  3. During wet weather events avoid allowing rain water to drip from rain gear or any other surface into sample bottles.
  4. Do not eat or drink during sample collection.
  5. Do not breathe, sneeze or cough in the direction of an open sample bottle.

8.2.2 Sample Collection

All samples will be collected as grab samples. At most stations, grab samples will be collected at approximately mid-stream, mid-depth at the location of greatest flow (where feasible) by direct submersion of the sample bottle depth. This is the preferred method for grab sample collection; however, due to sampling station configurations and safety concerns, direct filling of sample bottles is not always feasible. Sampling station configuration will dictate grab sample collection technique. Grab samples will be collected directly into the appropriate bottles as outlined in Table 8 (above).

The grab sample technique that may be employed is described below.

Where practical, all grab samples will be collected by direct submersion to mid-stream, mid-depth using the following procedures.

1. Wear clean powder-free nitrile gloves when handling bottles and caps. Change gloves if soiled or if the potential for cross-contamination occurs from handling sampling materials or samples;
2. Pre-label sample containers as described in **Sample Bottle Labeling** and **Sample ID Conventions**;
3. Submerge bottle to mid-stream/mid-depth, remove lid, let bottle fill, and replace lid;
4. Place sample on ice;
5. Collect remaining samples including control samples, if needed, using the same protocols described above;
6. Fill out COC form, note sample collection on field form, and deliver to appropriate lab.

8.3 Field Observations

In addition to the constituents listed in Table 6, field observations will be made at each sampling station. Observations will include color, odor, floating materials, presence of wildlife, as well as observations of contact and non-contact recreation. All comments on field observations will be recorded in the field log presented in Appendix 3.

8.4 Chain-of-Custody

Chain-of-custody (COC) forms will be filled out for all samples submitted to each laboratory. Sample data, sample location, sample collection crew names, and analysis requested shall be noted on each COC. See Appendix 4 for a blank COC form.

8.5 Transport to Lab

Samples will be stored in coolers with ice and delivered to the appropriate laboratories at the address provided in the field protocols section of this plan. Samples will be analyzed according to the methods listed in Table 6. In addition, Table 6 also provides detection limits and holding times.

8.6 Field Protocols

Field crews (2 persons per crew, minimum) will only be mobilized for sampling when weather conditions and flow conditions are considered to be safe. For safety reasons, sampling will occur during daylight hours. A sampling event should proceed in the following manner:

1. Before leaving the sampling crew base of operations, notify laboratory, confirm number and type of sample bottles as well as the complete equipment list.
2. Proceed to the first sampling station.
3. Fill-out the general information on the field log sheet.
4. Take field measurements and observations, and record on the field log sheet.
5. Take the samples indicated on the field log sheet in the manner described in this study plan. Take additional volume and blank samples for field-initiated QA/QC samples, if required. Place bottles in the coolers with ice. Double check against the log sheet that all appropriate bottles were filled.
6. Repeat the procedures in steps 3, 4, and 5 for each of the remaining sampling stations.

7. Complete the chain of custody forms using the field notes.
8. After collection is completed, deliver the samples to laboratory within 6 hours of the first sample collection:

Bacteria Analysis Laboratory, Inc. (BAL, Inc.)
29 N Lab St
Stockton, CA 95202
(xxx) xxx-xxxx

9.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality control samples shall be collected according to the schedule shown in Tables 9 and 10. Specific collection methods for each type of quality control sample type are described below.

9.1 Field Blank

Field blanks should be collected for the stations and events specified in Tables 9 and 10. The field crew will use blank water provided by the laboratory to generate field blanks by pouring blank water directly into the sample bottles. Field blanks should be submitted "blind" to the laboratory as station designation "FB".

9.2 Field Duplicates

Field duplicates shall be collected for the stations and events specified in Tables 9 and 10. Field duplicates shall be collected immediately following the collection of normal samples. In cases where multiple intermediate bottles are used for a single analysis, field duplicates and normal sample containers should be filled in an alternating sequence (i.e., normal-duplicate-normal-duplicate). Field duplicates should be submitted "blind" to the laboratory as station designation "FD".

9.3 Laboratory Duplicates

Laboratory duplicate analyses should be requested for all constituents for the stations and events specified in Tables 9 and 10. No special sampling considerations are required. However, additional sample volume must be collected, per laboratory requirements, for each analysis.

Table 9. Phase I Dry Weather Monitoring QA/QC Sample Collection Schedule

Site	Station ID	Event Number											
		1	2	3	4	5	6	7	8	9	10	11	12
Smith Canal	SC4-D	FB								FD			
	SC4-R	FD								FB			
	SC3-D		LD								FB		
	SC3-R		FB								LD		
	SC2-D			FB								FB	
	SC2-R			FD								FD	
	SC1-D				LD								LD
	SC1-R				FB								FB
Mormon Slough	MR4-D					FB							
	MR4-R					FD							
	MR3-D						FB						
	MR3-R						LD						
	MR2-D							FD					
	MR2-R							FB					
	MR1-D								FB				
	MR1-R								LD				

Site	Station ID	Event Number											
		13	14	15	16	17	18	19	20	21	22	23	24
Smith Canal	SC4-D					FD							
	SC4-R					FB							
	SC3-D						FB						
	SC3-R						LD						
	SC2-D							FD					
	SC2-R							FB					
	SC1-D								LD				
	SC1-R								FB				
Mormon Slough	MR4-D	FB								FB			
	MR4-R	LD								FD			
	MR3-D		LD								LD		
	MR3-R		FB								FB		
	MR2-D			FB								FB	
	MR2-R			FD								FD	
	MR1-D				FB								FD
	MR1-R				LD								LD

FB = Field Blank
LD = Lab Duplicate
FD = Field Duplicate

Table 10. Phase I Wet Weather Monitoring QA/QC Sample Collection Schedule

Site	Station ID	Storm Event Number				
		1	2	3	4	5
Smith Canal	SC4-D	FB				FB
	SC4-R	FD				LD
	SC3-D		LD			
	SC3-R		FB			
	SC2-D			FB		
	SC2-R			FD		
	SC1-D				LD	
	SC1-R				FB	
Mormon Slough	MR4-D	LD				FB
	MR4-R	FB				LD
	MR3-D		FB			
	MR3-R		FD			
	MR2-D			FB		
	MR2-R			LD		
	MR1-D				FB	
	MR1-R				FD	

Appendix 1: Sampling Stations

SMITH CANAL

The entire length of the Smith Canal is 303(d) listed for bacteria. Four monitoring sites are located on the Smith Canal. The most upstream site, Yosemite Lake, will allow quantification of bacteria concentrations in the canal at its origin (Legion Park). The downstream sites will allow quantification of bacteria concentrations as the river traverses the urbanized area. Site description will proceed from upstream to downstream. There are several viable receiving water sampling locations in Legion Park. The most appropriate location is the near the outfall of the Legion Park pump station (Figure 1).

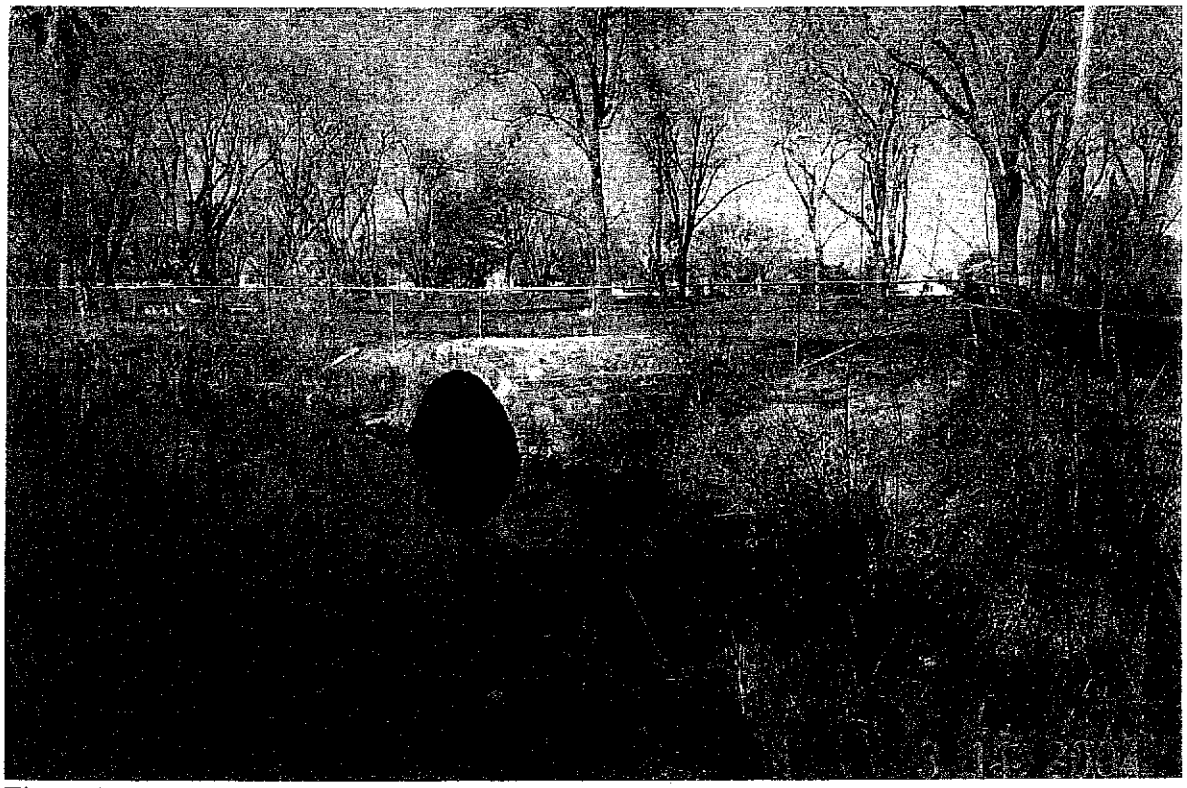

Figure 1

Likewise, the most appropriate discharge sampling location is the wet well or junction box at the Legion Park pump station (Figure 2).

Figure 2

A supplementary receiving water sampling site is located at the north side of the park at Yosemite (Figure 3).

Figure 3

The next downstream sampling site for receiving water is at the Pershing Bridge, where there is an existing City monitoring station (Figure 4).

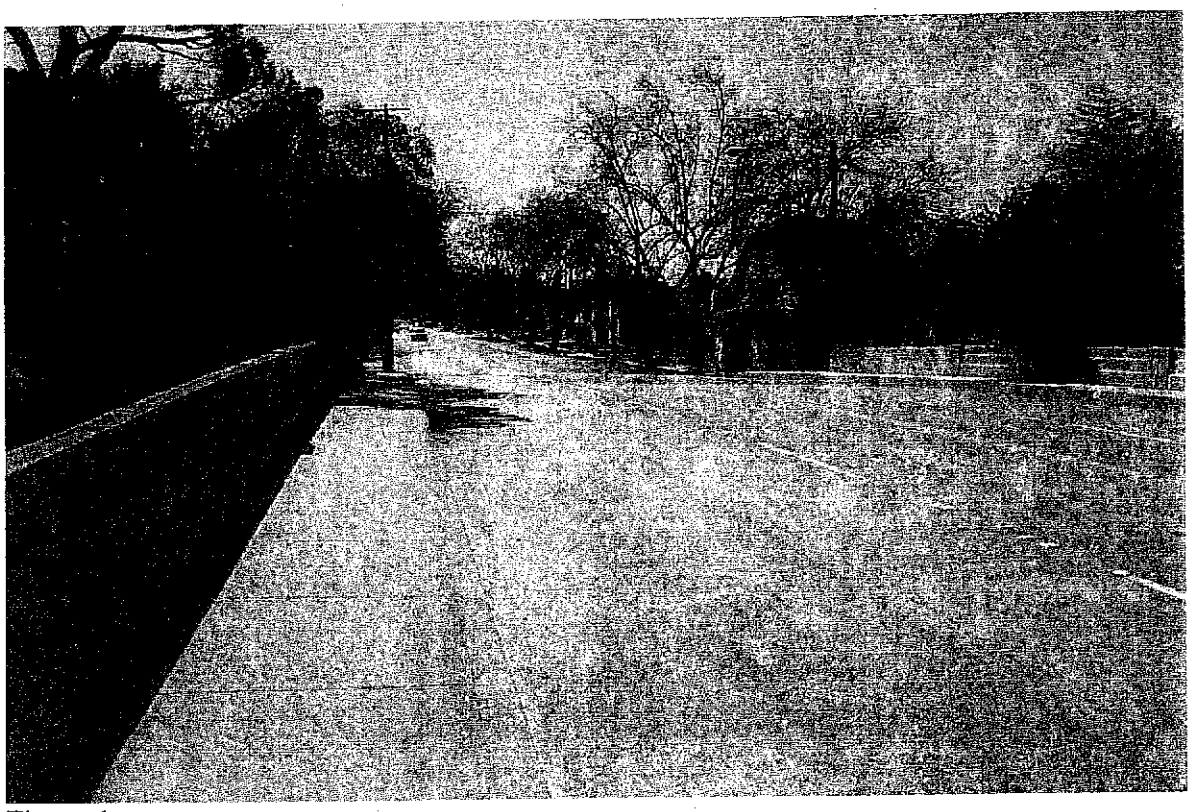

Figure 4

The third downstream receiving water sampling location is the pedestrian footbridge off Shimizu Drive at Ryde Avenue (Figure 5).

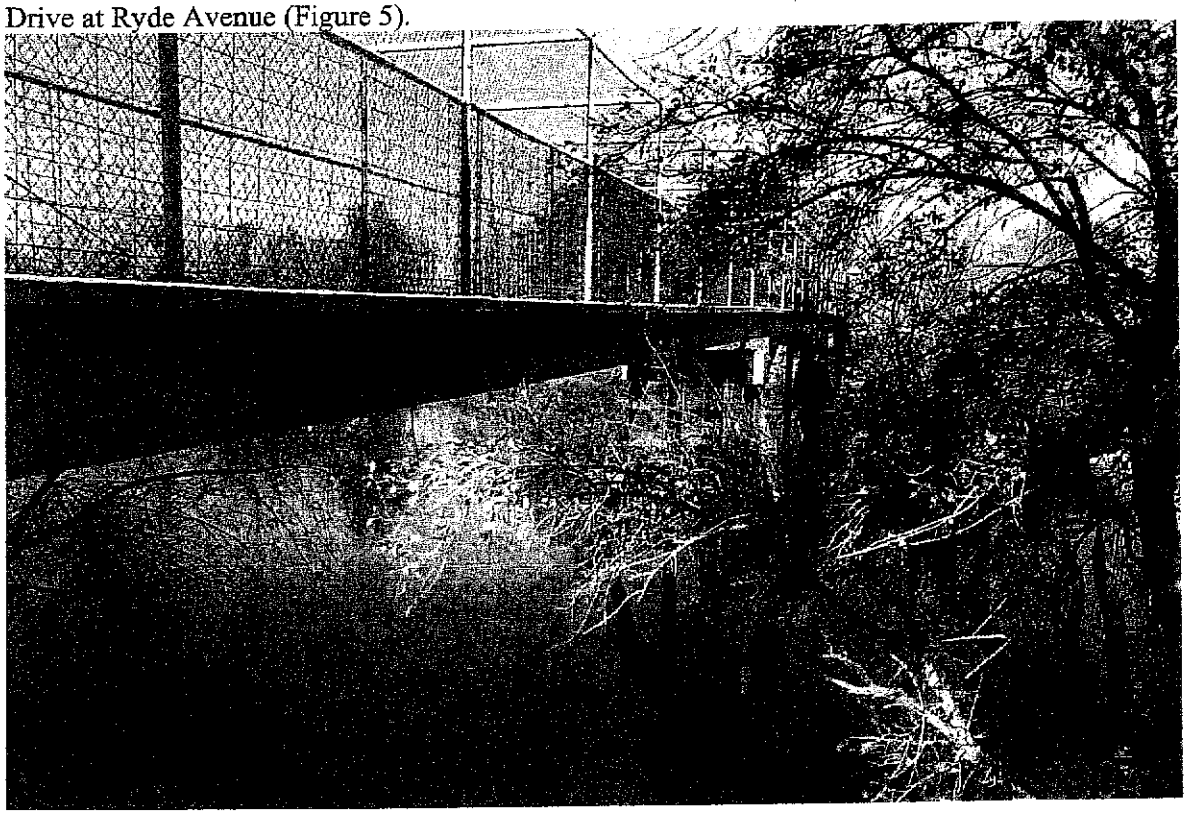

Figure 5

The discharge sampling location is the wet well of the Ryde Avenue pump station (Figure 6).

Figure 6

The final receiving water and discharge sampling location is at Occidental Avenue and Shimizu Drive (on the south side of Smith Canal) (Figure 7).

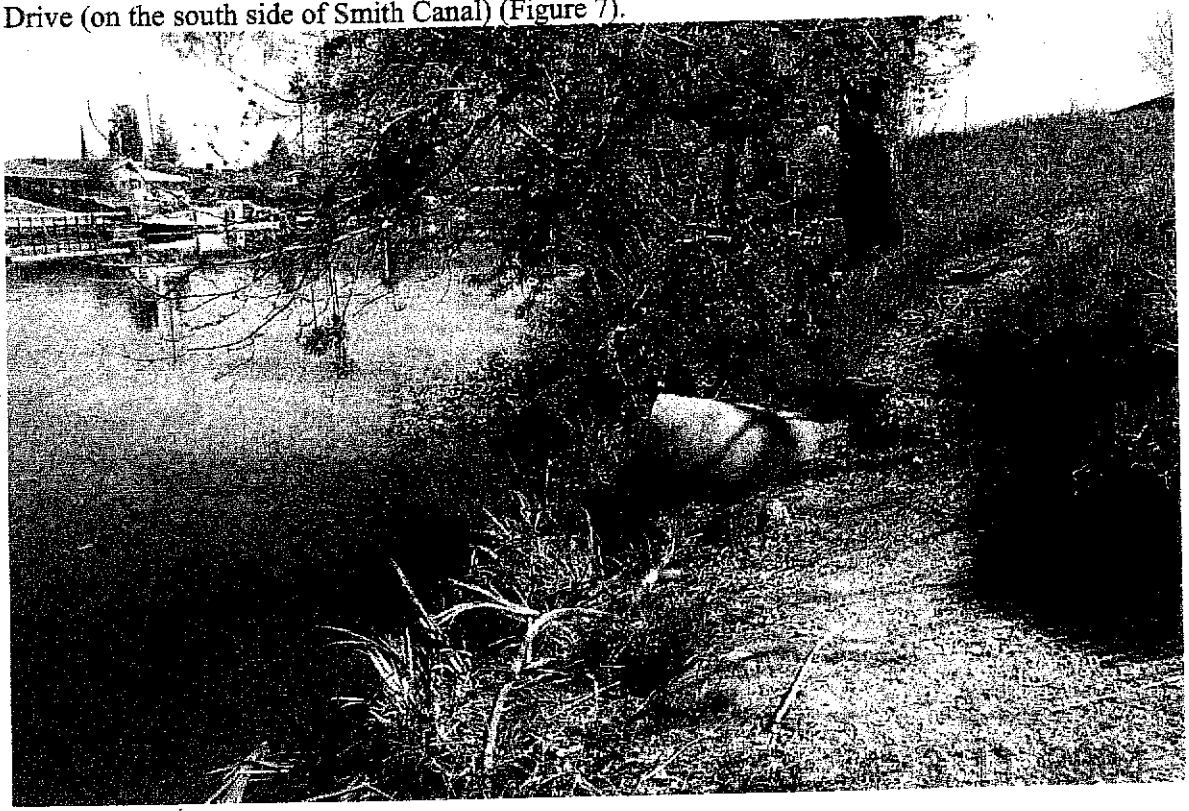

Figure 7

MORMON SLOUGH

Mormon Slough is 303(d) listed for bacteria from the confluence with the Stockton Diverting Canal to the confluence with the Deep Water Channel. Mormon Slough is known to be frequented by homeless people. Four monitoring sites are located on Mormon Slough. The most upstream site, Wilson Way, will allow quantification of bacteria concentrations in the slough at the point where it contains water on a permanent basis. The downstream sites will allow quantification of bacteria concentrations as the slough traverses the urbanized area. Site description will proceed from upstream to downstream. The second discharge sampling site is located in the discharge or wet well of the Commerce Street (Figures 8).

Figure 8. Commerce Street sampling site is in the immediate background

A receiving water sampling site is located downstream of the box culvert at Commerce Street (Figure 9).

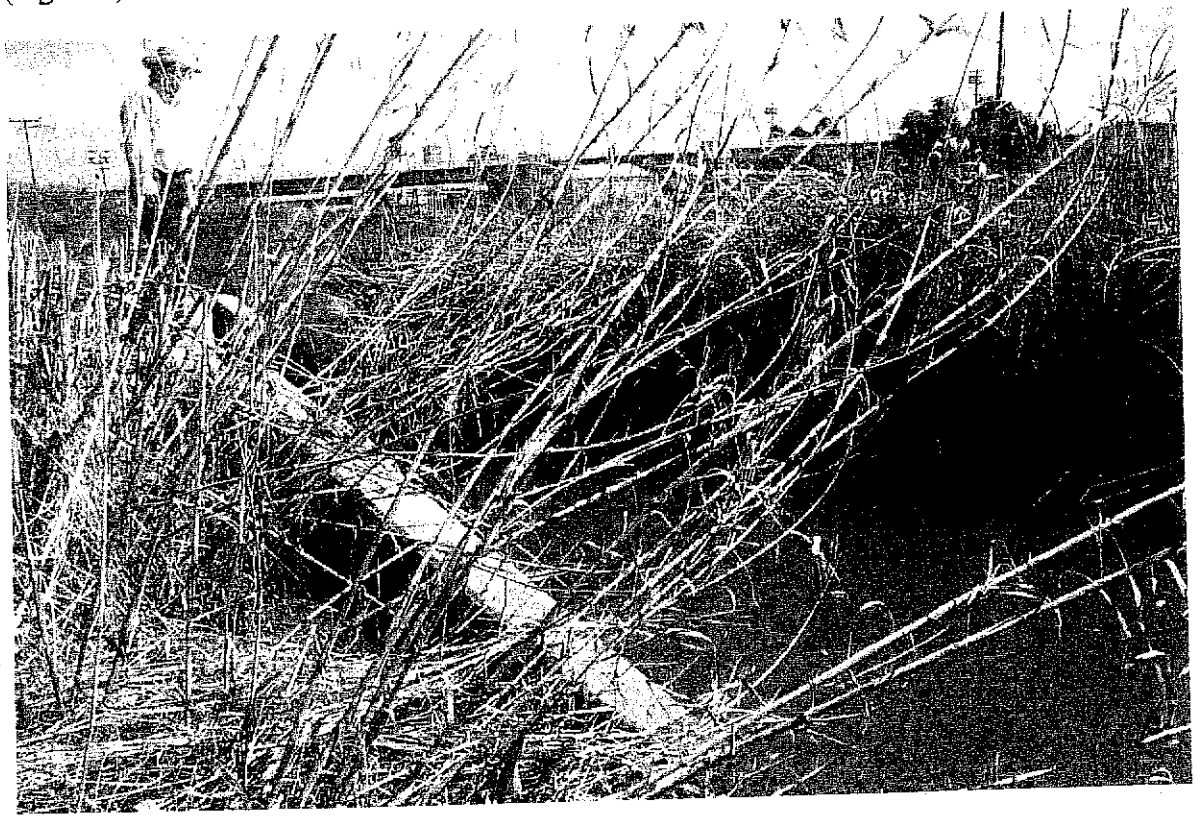

Figure 9

The next downstream sampling site for receiving water is at the Crosstown Overcross near Lincoln Avenue, where there is easy access to the slough (Figure 10).

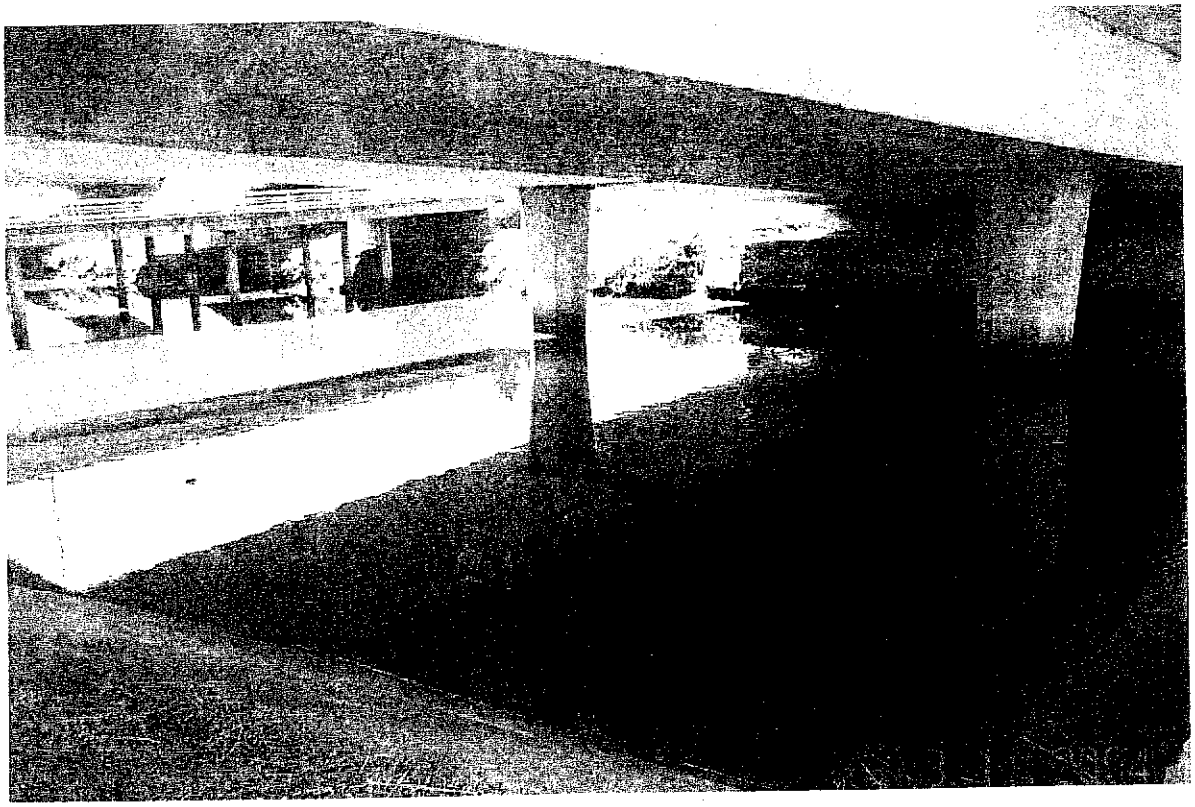

Figure 10

The discharge sampling location is the outfall just north of the bridge (Figure 11).

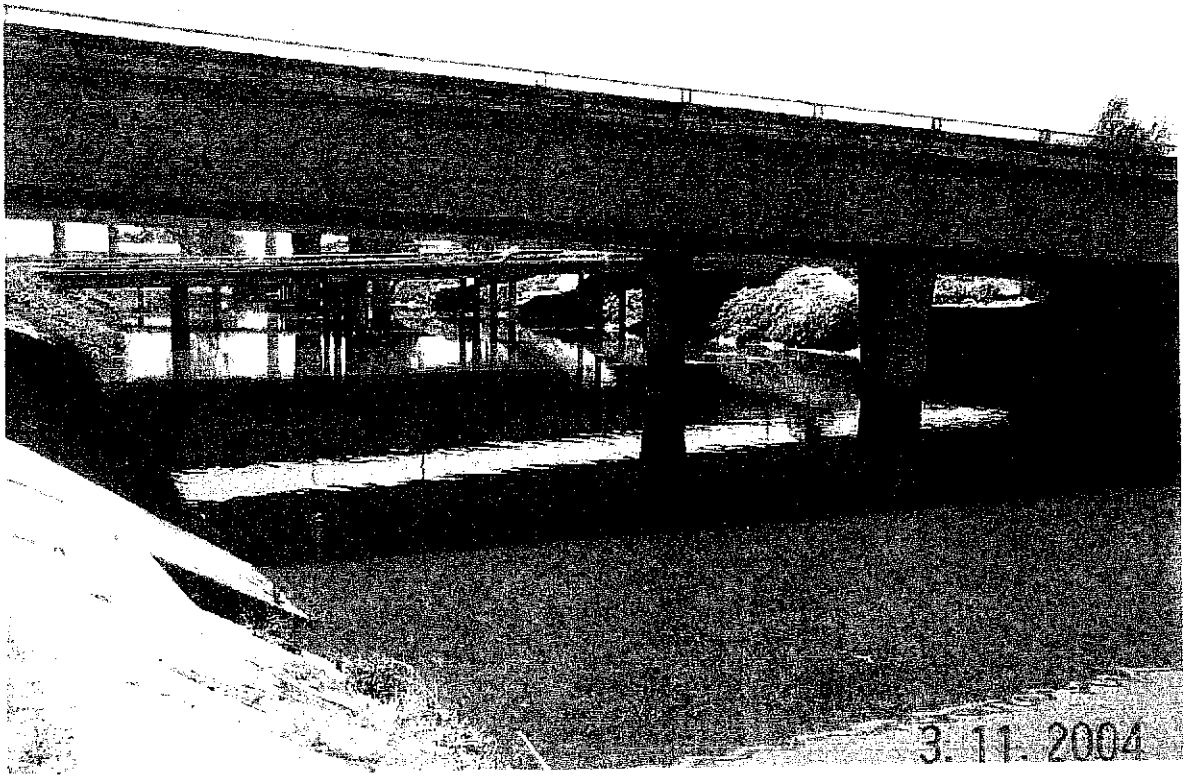

Figure 11

The third receiving water sampling location is the boat ramp at Morelli Park (Figure 12).

Figure 12

APPENDIX 2: EXAMPLE EVENT SUMMARY SHEET

Dry Weather Sampling Event #1 – July 6, 2004
Mormon Slough

Event Summary

Sample Type	Requirements	Bottles	Lab
MR4-D-01			
Discharge:	*E. coli* Total Coliform Fecal Coliform	125 mL sterile plastic	BAL, Inc
MR4-R-01			
Receiving Water:	*E. coli* Total Coliform Fecal Coliform	125 mL sterile plastic	BAL, Inc
MR3-D-01			
Discharge:	*E. coli* Total Coliform Fecal Coliform	125 mL sterile plastic	BAL, Inc
MR3-R-01			
Receiving Water:	*E. coli* Total Coliform Fecal Coliform	125 mL sterile plastic	BAL, Inc
MR2-D-01			
Discharge:	*E. coli* Total Coliform Fecal Coliform	125 mL sterile plastic	BAL, Inc
MR2-R-01			
Receiving Water:	*E. coli* Total Coliform Fecal Coliform	125 mL sterile plastic	BAL, Inc
MR1-D-01			

Discharge:	*E. coli* Total Coliform Fecal Coliform	125 mL sterile plastic	BAL, Inc
MR1-R-01			
Receiving Water:	*E. coli* Total Coliform Fecal Coliform	125 mL sterile plastic	BAL, Inc

APPENDIX 3: FIELD LOG

GENERAL INFORMATION

Station ID: _____ Date: _____ Time: Arrival _____
Departure_____

Sampler's Name(s): _____

OBSERVATIONS

Weather: _____

Floating material or debris: _____

Oil (extent): _____ Water color or odor: _____

Photograph No. (if taken): _____

Recreation uses observed: _____

Other Notes (presence of algae, wildlife observations, etc.):

_____

_____

WATER QUALITY MEASUREMENTS

SAMPLE COLLECTION

Enterococcus Time: _____ Volume: _____

E. coli Time: _____ Volume: _____

Fecal Coliform Time: _____ Volume: _____

APPENDIX 4: EXAMPLE BLANK CHAIN OF CUSTODY FORM

CHAIN-OF-CUSTODY PAGE ___ OF ___

COMPANY NAME:	COMMENTS/SPECIAL INSTRUCTIONS:
ATTN:	
ADDRESS:	
PHONE:	
FAX:	
E-MAIL:	
PROJECT NAME:	SEND INVOICE TO:
PROJECT NUMBER:	P.O. / CONTRACT NO:

ANALYSIS(ES) REQUESTED

TOXSCAN INC.
42 Hangar Way
Watsonville, CA 95076
PHONE: 831-724-4522
FAX: 831-724-3188
E-Mail:

LAB USE ONLY
STORAGE LOCATION
FREEZER #
REFRIGERATOR #
SHELF#

Lab Use Only ID Number	Client Sample Identification	Sample Information			Bottle or Container Information:				CHECK THE APPROPRIATE BOX BELOW							SAMPLE CONDITION
		Sampling Date	Sampling Time	Sample Type	Sample Preservative	Bottle Type	Bottle Size	No. of Bottles								

SAMPLER'S SIGNATURE AND PRINTED NAME:

RELINQUISHED BY (SIGNATURE AND PRINTED NAME):	RECEIVED BY (SIGNATURE AND PRINTED NAME):	DATE:	TIME:

APPENDIX **B**

Microbial Source Tracking: A Review of Current Methods and Recommendations

Technical Memorandum

LARRY WALKER ASSOCIATES

DATE: April 1, 2004

TO: Amin Kazemi, City of Stockton

SUBJECT: Microbial Source Tracking: A Review of Current Methods and Recommendations

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INTRODUCTION

Recent monitoring efforts have identified bacteria (pathogens) as an impairment to six waterbodies within the City of Stockton. The State's Clean Water Act Section 303(d) list identifies all six as not attaining water quality standards due to elevated levels of bacteria. Understanding the origin of fecal pollution is paramount in undertaking any actions necessary to remedy the problem. Traditional and alternative indicator microorganisms have been used for many years to predict the presence of fecal pollution in water. The purpose of this Technical Memorandum is to review the latest advances in Microbial Source Tracking (MST) and make recommendations of appropriate techniques for identifying microbial sources for the City of Stockton's Pathogen Plan.

Maintenance of the microbiological quality of waterbodies used for drinking water and recreation is imperative, as contamination of these waterbodies by fecal material can potentially result in risks to human health. Traditional and alternative indicator microorganisms have been used for over a century in predicting the presence of fecal pollution in water. However, it is now well established that the majority of these microorganisms are not limited to existence in humans and can also exist in the intestines of many other warm-blooded animals. Also, due to the ubiquitous nature of these microorganisms, the effectiveness of using traditional indicators to predict the presence of human or animal fecal pollution is limited. Recently, the usefulness of these traditional indicators as detection tools has been significantly enhanced by the development of analytical testing methods and analysis techniques that can define the specific sources of these organisms. This concept, that the origin of fecal pollution can be traced using an array of new methods, has been termed microbial source tracking.

MICROBIAL INDICATORS OF FECAL POLLUTION

Indicator microorganisms are used to detect the presence of and determine the potential risk associated with pathogenic microorganisms. Indicator microorganisms are useful in that

they allow public agencies to avoid the need to analyze for every pathogen that may be present in water. The ideal indicators are nonpathogenic, rapidly detected, easily enumerated, have survival characteristics similar to those of the pathogens of concern, and can be strongly associated with the presence of pathogenic microorganisms.

Total and Fecal Coliforms

Total and fecal coliforms have been widely used for many years as indicators for determining the microbiological quality of waterbodies. In recent years, scientists have increased their knowledge of the ways in which the coliforms' ecology, prevalence, and resistance to stress differ from those of many of the pathogenic microorganisms they are proxy for. It now appears that these differences are so great that they severely limit the usefulness of the coliforms as indicators of fecal pollution. Therefore, additional microbes have been suggested for use as alternative indicators, including *E. coli*, enterococci, and *Clostridium perfringens*.

E. coli

E. coli has been used as an indicator of fecal pollution for many years. It has several characteristics of a good fecal indicator, such as not normally being pathogenic to humans, and it is present at concentrations much higher than the pathogens it predicts. However, recent studies have suggested that *E. coli* may not be a reliable indicator in tropical and subtropical environments because it can replicate itself in contaminated soils.

Enterococcus spp.

The enterococcus group is a subgroup of the fecal streptococci and is differentiated from other streptococci by their ability to grow in high salinity, high pH and high temperature. Enterococci have been successfully employed as indicators of fecal pollution and are especially reliable as indicators in marine environments and recreational waters. However, environmental reservoirs (e.g. animals) of enterococci exist and these microorganisms may replicate themselves once they are introduced into the environment.

Clostridium perfringens

C. perfringens is a pathogenic bacterium found in human and animal feces. Although there is considerable controversy surrounding the use of *C. perfringens* as a water quality indicator because of its ability to persist in the environment, a number of scientists continue to recommend its use. This is particularly true for situations where the prediction of the presence of viruses or remote fecal pollution is desirable.

While the above alternative microbial indicators can be useful for predicting the presence of fecal contamination, their shortcomings as indicators of human fecal pollution have become more and more apparent. The advent of microbial source tracking technologies has enhanced the ability of these and traditional indicator microorganisms to be used as tools for predicting potential sources of human fecal pollution as well as other fecal sources associated with impaired waterbodies.

MICROBIAL SOURCE TRACKING METHODOLOGY

Various methods have been proposed to characterize indicator microorganisms by detecting subtle differences present within different groups of microorganisms. These differences can subsequently be used to identify the host or environment from which the microorganisms were derived. There are currently four general categories of microbial source tracking methodology:

- Microbiological Methods
- Phenotypic Methods
- Genotypic Methods
- Chemical Methods

RATIONALE BEHIND MICROBIAL SOURCE TRACKING

Recombinant DNA technology can be used to differentiate different genetic lineages of bacteria found within different animal hosts. However, this assumes that within a species of bacteria, there are members or subgroups that have become more adapted to a particular host or environment for various reasons, including differences in pH, availability of nutrients, and receptor specificity. The second assumption is that once these microorganisms become adapted to a particular organism and establish residency, the progeny produced by subsequent replications will be genetically identical. Therefore, over time, a group of organisms within a particular host or environment should possess a similar or identical genetic fingerprint, which will differ from those organisms adapted to a different host or environment.

Microbial source tracking methodologies that focus on phenotypic differences within different lineages of bacteria usually focus on traits that may have been acquired from exposure to different host species or environments. Traditionally, these methods have targeted multiple antibiotic resistance (MAR) patterns, cell surface or flagellar antigens, or biochemical tests designed to identify variations in the utilization of various substrates that may be found within a particular host environment.

Direct monitoring for human pathogens (or more specifically, the pathogen's nucleic acids), such as viruses and parasites (e.g. *Cryptosporidium* and *Giardia* species), has also been used as a means of detecting the presence of human fecal pollution in water. Directly monitoring for pathogens provides unequivocal evidence of their presence and thus circumvents the need to test for often-ambiguous indicator microorganisms; however, many of these pathogens are not readily detectable in the environment as they are often present in very low numbers.

Various chemical compounds have also been proposed as indicators of human- or animal-derived fecal pollution. The use of these chemical indicators poses problems, as parallels between the survival, transport, and persistence of these chemicals and the pathogens they are being used to predict are proving difficult to discern. This withstanding, certain chemicals and metabolites can be associated with various types of fecal pollution, assuming that human and animal communities utilize different substances or produce different metabolic by-products that can subsequently be traced back to the source of the pollution in the environment.

MICROBIOLOGICAL METHODS

Numerous "standard" microbiological methods have been used in discerning between various groups of fecal indicators. These include indicator ratios, testing for groups of highly specific bacteria and the viruses which attack them, as well as avoiding the use of indicator species and testing for human pathogens directly. However, some of these techniques have serious disadvantages, as outlined below. Despite these drawbacks, several microbiological methods have been successfully used in microbial source tracking studies.

Fecal coliform/fecal streptococcus ratio

To meet the challenge of identifying sources of fecal pollution, various microbiological methods have been proposed. Initially, the ratio of fecal coliforms to fecal streptococci was proposed. A ratio of >4.0 would indicate human pollution and a ratio of ≤0.7 would indicate non-human pollution. The rationale behind the use of this method was that human feces contain higher fecal coliform counts, while animal feces contain higher levels of fecal streptococci. The advantage of using this method is its ability to provide results within a relatively short time. Additionally, the method requires minimal expertise to perform. However, this approach has been shown to be unreliable due to variable survival rates of fecal streptococci species, variations in detection methods, and variable sensitivity to water treatments and has been more or less abandoned as an approach to microbial source tracking.

Bifidobacterium spp.

These organisms have been investigated as potential candidates for use as indicators of human fecal pollution because they are rarely found in animals. Additionally, those species that are found in animals tend to be isolated at different frequencies from different animals. Also, the ability of human isolates to ferment sorbitol has been used to further differentiate these organisms as being human-derived. The use of these microorganisms as indicators of human fecal pollution holds some promise; however, the survival of these organisms has been shown to be highly variable. The advantage of using an anaerobic bacterium such as *Bifidobacterium* spp., however, is its inability to reproduce once deposited in the environment. Therefore, if detected, it can provide reasonably good evidence of recent fecal contamination. Because survival issues tend to reduce or alter the numbers of *Bifidobacterium* spp. present in the environment, new techniques must be developed that increase both the specificity and sensitivity of detection of these organisms before this method can be used as a reliable indicator of fecal pollution.

Bacteroides fragilis bacteriophage

The *Bacteroides* group of bacteria is present in high numbers in both human and animal intestines. This finding prompted the idea that bacteriophage, a virus that specifically infected specific strains of *Bacteroides,* could be used as indicators of human fecal pollution. The detection of *B. fragilis* bacteriophage has the advantage of being a highly specific method for tracking the source of human fecal pollution. These phage do not replicate in the environment, and their presence in the environment has been found to be significantly correlated with the presence of human enteric viruses. However, the absence of *B. fragilis* phage in highly polluted waters and sewage in some areas of the United States and the inherent difficulty in performing the technique limit the usefulness of this method.

F-specific RNA coliphage

Coliphages are viruses that infect *E.* coli. Investigators have also reported that animal and human feces contain specifically different serotypes of RNA coliphages, suggesting that phage can be used to predict sources of pollution. There are two main groups of coliphages: somatic coliphages and male-specific (F+) coliphages. Significant genetic differences have been shown to be present between and within members of each group of bacteriophage, though the F+ RNA bacteriophage have been more fully characterized. Therefore, the majority of microbial source tracking research has focused on the F+ RNA coliphages. There are four main subgroups of F+ RNA coliphages: group I, group II, group III, and group IV. Members of groups II and III have been shown to be highly associated with human fecal contamination and/or domestic sewage, while group IV coliphages have a higher incidence in wastes associated with animals and livestock. Group I coliphages are present in feces and sewage from both humans and animals. The apparent differences in host selection for the various groups of F+ RNA coliphage have been utilized to predict the presence of fecal contamination based on the presence or absence of a particular group of coliphage.

Once detected, the phage can be further characterized as being human or animal derived by immunological or genetic methods. Because the number of bacteriophage present in the environment is often considerably lower than that of traditional bacterial indicators, it is important that detection be sensitive and include both enrichment procedures and direct assay. Furthermore, if a mixed contamination event occurs, then water samples must be collected and assayed immediately so that die-off of a particular group of coliphage does not occur, which would falsely indicate the presence of only one group or another. Although the host specificity (or at least the apparent general association of particular groups of coliphage with either humans or animals) is well documented, efforts to isolate F+ RNA coliphage have revealed that only a small percentage of human fecal samples contain these phage. However, F+ RNA bacteriophage predominate in domestic sewage, which suggests an ability for these coliphage to proliferate or be released in the sewage environment.

Human Enteric Viruses

More than 100 different enteric viruses are associated with the human gastrointestinal tract. Unfortunately, many of these viruses are not easily cultivated in environmental samples. Several methods have been devised which concentrate and cultivate these organisms. They have been shown to be useful in detecting the presence of human fecal contamination. Studies have shown that outbreaks of gastroenteritis have been associated with waterbodies which have acceptable coliform counts. Likewise, bacterial indicators have been shown to be unreliable indicators of the presence of enteroviruses and other enteric viruses. By monitoring directly for human enteric viruses, the uncertainty associated with the use of fecal indicators can be avoided.

Monitoring directly for human pathogens provides valuable information as to the quality of the waterbodies being evaluated. Molecular methods (PCR and reverse transcription-PCR) can be used to detect noncultivable viruses. However, nonviable viruses are also detected by this procedure. This problem is partially remedied by using cell culture cultivation followed by PCR or reverse transcription-PCR. Finally, as with any presence-absence test, the inability to detect an enteric virus cannot be construed as evidence of its absence. Therefore, this method should be used in conjunction with one or more additional methods for predicting the presence of fecal pollution and enteric pathogens.

PHENOTYPIC METHODS

Numerous phenotypic methods have been suggested for use in discerning between various groups of bacteria. These include biochemical tests, phage (virus) susceptibility, outer membrane protein profiles, antibody reactivity, fimbriation, bacteriocin production and susceptibility, as well as other methods. However, these systems have serious disadvantages, including unstable phenotypes, low sensitivity at the intraspecies level, and limited specificity. Despite these drawbacks, several phenotypic methods have been successfully used in bacterial source tracking (BST) studies.

Multiple Antibiotic Resistance (MAR) analysis

MAR analysis is a method that has been used to differentiate bacteria (usually *E.* coli or fecal streptococci) from different sources using antibiotics commonly associated with humans and animals. This method is based on the concept that bacteria present in the gut of various types of animals (including humans) are subjected to different types and concentrations of antibiotics. Over time, selective pressure within a specific group of animal selects for bacteria that have specific "fingerprints" of resistance to a given antibiotic. This procedure involves the isolation and culturing of a target bacteria, then replica plating the isolates on media containing various antibiotics at various concentrations. These plates are then incubated and the bacteria are scored based on their susceptibilities to various antibiotics. Theses scores are then used to generate an antibiotic resistance profile. These "fingerprints" are then characterized, analyzed by discriminate (or cluster) analysis, and compared to a reference database to identify an isolate as being either human or animal derived.

The MAR technique has been shown to be successful in discriminating *E. coli* or fecal streptococci isolated from specific animal species, including wildlife, agricultural animals (cattle, pigs, horses, and chickens), and humans. However, antibiotic resistance is often carried on plasmids (small circular double-stranded segments of DNA that are replicated inside the bacteria independently of the chromosomes) which can be lost from cells via cultivation and storage or by changes in environmental conditions. This factor could potentially change the apparent origin of an organism after its persistence in the environment. In addition, strains from different locations may show variations in specific sensitivities due to variable antibiotic use among humans and other species. For these reasons, large databases may need to be compiled that contain antibiotic resistance profiles from multiple organisms from a large geographic area. Furthermore, antibiotic sensitivity is not useful in situations where the isolates under study show no significant resistance patterns yet come from different animal species.

Immunological methods

Serogrouping of microorganisms based on the presence of different antigenic determinants has been used by several investigators to discriminate *E. coli* from various sources. It has been reported that different serotypes of *E.* coli are associated with different animal sources, although many serotypes are also shared among humans and animals. However, one of the drawbacks to this method is the need for a large bank of antisera. Some researchers have suggested that this method be used in conjunction with another method,

such as ribotyping, which would allow the testing of a limited number of serotypes. The possibility of testing for only certain serotypes makes this a potentially valuable method to be included in the microbial source tracking "toolbox."

GENOTYPIC METHODS

With the recent explosion of recombinant nucleic acid (DNA and RNA) technology, numerous genotypic methods have been devised and used in discerning between various groups of bacteria and viruses. These include the use of electrophoresis, polymerase chain reaction (PCR), ribotyping and the use of molecular markers. These methods have shown tremendous promise and remain an area of tremendous interest with much ongoing research at numerous universities. These methods have been successfully used in several microbial source tracking studies.

Pulse-field Gel Electrophoresis (PFGE)

Pulsed-field gel electrophoresis (PFGE) is a method of DNA fingerprinting whereby DNA fingerprints are generated after treatment of genomic bacterial DNA with rare cutting restriction endonucleases. PFGE has been a very useful technique in determining bacterial relatedness and in some epidemiological studies. However, additional published research using this technique for BST is absent, and its worth for this purpose has not been fully determined.

Repetitive Element Polymerase Chain Reaction (PCR)

Repetitive element PCR uses specific sequences of genetic code ("primers") corresponding to interspersed repetitive DNA elements present in various locations within the genetic materials of microorganisms to generate highly specific genetic "fingerprints". Three methods of repetitive sequence analysis have been used, with each targeting a specific family of repetitive elements. These methods include repetitive extragenic palindromic sequence PCR (REP-PCR), enterobacterial repetitive intergenic consensus sequence PCR (ERIC-PCR), and PCR with extragenic repeating elements (BOX-PCR). The REP primer set generally generates a lower level of complexity, while the ERIC primer set is more sensitive to suboptimal PCR conditions, such as the presence of contaminants in the DNA preparation. Generally, the BOX primer is used in cases where a detailed characterization is needed, as this primer generates robust fingerprints and generally yields a highly complex pattern of amplified fragments. This method has been used previously to differentiate between closely related strains of bacteria. For these reasons, BST research initially focused on the use of the BOX primer in performing REP-PCR. The genetic fingerprint generated using BOX-PCR contains several visible bands or patterns, which can subsequently be analyzed, categorized by host source, and used to construct a database to which fingerprints from unknown isolates can be compared. Successful identification of an unknown bacterial isolate also requires that a reference database be established, and additional known isolates must be fingerprinted from a large geographic region in order to assess the potential universal application of this procedure. Questions have also arisen as to the reproducibility of this method.

Ribotyping

Ribotyping is a method of DNA fingerprinting whereby highly conserved rRNA genes are identified using oligonucleotide probes after treatment of genomic DNA with restriction endonucleases. The method is a labor-intensive procedure that involves bacteriological culture and identification, DNA extraction, gel electrophoresis, Southern blotting, and discriminant analysis of the resulting DNA fingerprints. Ribotyping has proven to be a very useful epidemiological technique for use with various bacteria, including *E. coli* and *Vibrio cholera* (the pathogen which causes Cholera).

Ribotyping has also been reported to effectively track human and nonhuman sources of pollution. Variations of the ribotyping procedure usually involve the use of different restriction enzymes, the use of alternative detection methods during the Southern blotting procedure (colorimetric or radioactive), or variations in analysis and interpretation of ribotype profiles (discriminant analysis versus 100% similarity). As with other DNA fingerprinting methodologies, the success of this procedure usually depends on the size of the "known-source" reference fingerprint database to which a ribotype profile from an unknown isolate must be compared. The inability of many laboratories to compile a database that contains enough isolates to which unknown profiles can be compared may be one limitation of this procedure, as ribotyping has been shown to lose its effectiveness when isolates are collected from a broad geographic area. Additional factors such as differences in the diet of the host animal have also been suggested as a reason for variations in ribotype profiles. Therefore, databases either may need to be extremely large and contain isolates from a very broad geographic region or must be designed exclusively for a specific watershed with defined potential impacts. Finally, although this method has proven successful in some aspects, it is expensive and labor-intensive, unless the procedure is streamlined and performed routinely.

Host-specific molecular markers

Detection of host-specific molecular markers in raw water samples holds promise as an effective method for characterizing a microbial population without first culturing the organisms in question. Rapid tests that discriminate human fecal pollution from human and bovine fecal pollution use length heterogeneity PCR and terminal restriction fragment length polymorphism analysis to characterize members of the *Bacteroides-Prevotella* group and the genus *Bifidobacterium*. The use of *Bacteroides* spp. is desirable, as anaerobic bacteria are less likely to reproduce once introduced in the environment. They have been detected in water by PCR for 4-5 days at temperatures around 14°C. In addition, assaying for a battery of specific toxin genes or additional host-specific genes by PCR has shown some promise for differentiating bacteria based on their pathogenic properties and the hosts they target. This approach offers the advantage of circumventing the need for a culturing step, which allows a more rapid identification of target organisms. Assaying for toxin or adhesion genes has not been thoroughly investigated and is complicated by the fact that many organisms do not contain these genes regardless of their host specificity.

CHEMICAL METHODS

In addition to the more standardized biological approaches to microbial source tracking some chemical methods have been proposed. The rationale behind the use of these methods aims at detecting certain human-specific chemicals which are generally associated with human

fecal pollution. To date, these methods have limited promise and their use remains somewhat controversial.

Caffeine

Caffeine is present in several beverages, including coffee, tea, soft drinks, and in many pharmaceutical products. It is excreted in the urine of individuals who have ingested the substance, and subsequently, it has been suggested that the presence of caffeine in the environment would indicate the presence of human sewage. Caffeine in domestic wastewater have been measured at elevated levels. Levels in receiving waters are much lower due to significant dilution, and little is known about the fate of caffeine in the environment once it has been deposited.

Coprostanol

Coprostanol is a fecal stanol that is formed during catabolism of cholesterol by indigenous bacteria present in the gut of humans and higher animals and is the primary stanol detected in domestic wastewater. For this reason, it has been proposed as a chemical indicator of human fecal pollution. Feces from pigs and cats also known to contain coprostanol, but at levels that were 10-fold lower than those found in humans. Additional fecal stanols are predominant in herbivores, such as cows, horses, and sheep, suggesting potential use of this chemical as an indicator of fecal pollution from these sources.

While initial results seem promising, overall, the methodologies used for the detection of human-specific chemical substances in water are tedious and lack the desired sensitivity to be considered as universal indicators of human fecal pollution. Furthermore, to date, no direct relationships have been made between the presence of these chemical indicators and pathogenic organisms.

RECOMMENDATIONS

The following recommendations are made with respect to the utilization of MST in detecting and quantifying bacterial sources in the City of Stockton.

- Utilize the approach based on the 16S rRNA gene of the non-spore forming, obligate anaerobe *Bacteroides-Prevotella* (genotypic method). Based on PCR followed by T-RFLP or PCR amplification alone using host-specific primers. The advantage of T-RFLP is high through-put of samples and analysis using an automated DNA sequencer.

- Determine the survival of *Bacteroides-Prevotella* in situ in the waterbody being examined (field experiment).

- Incorporate quantitative detection (by real time PCR) of marker gene sequences for human and non-human fecal *Bacteroides-Prevotella* as soon as they become available.

The *Bacteroides* method is rapid, relatively inexpensive, and easy to perform when conventional PCR is employed (qualitative analysis). The assay can be adjusted to target either rRNA or rDNA. rRNA is a better indicator of cell viability, and its use is more indicative of recent fecal contamination. The present usage of the *Bacteroides* method in watersheds has involved only qualitative testing. If desired, end point dilution analysis of samples can be incorporated using the MPN-PCR or replicate limiting dilution analysis approach, which give an estimate of the cell numbers in a sample (semi-quantitative approach). However, these procedures involve considerably more effort and are not recommended if real-time PCR (see below) is available.

Real-time PCR is emerging as an important tool for the true quantitative analysis of microbial cells in environmental samples. As soon as an adequate detection system consisting of a primer set plus internal probe for the differentiation of *Bacteroides* from human and non-human sources becomes available (an assay has been developed by Oregon State University), the use of real-time PCR analysis is recommended. Microbial source tracking is not expected to occur until 2005–2006, when these primers should be ready for use in the City of Stockton's Pathogen Plan.

Table 1. Pros and Cons of Existing Microbial Source Tracking Methods.

Method	Pros	Cons
Fecal coliform/fecal streptococci ratio	1.) Simple to perform.	1.) Fecal streptococci have variable survival rates which can alter ratios.
Bifidobacterium sp.	1.) Sorbitol fermentors can be very human specific.	1.) Low numbers present in the environment. 2.) Variable survival rates. 3.) Culture methods may be difficult and expensive to implement.
B. fragilis HSP40 bacteriophage	1.) Very human specific. 2.) Test is easy to perform.	1.) Not present in sewage in some areas.
F+ RNA bacteriophage	1.) Groups well correlated with human & animal sources. 2.) Simple to perform	1.) Unreliable in marine waters due to variable survival rates.
Human enteric virus	1.) Human specific. 2.) No need to use indicators.	1.) Low numbers present in environment. 2.) Labor intensive.
Multiple Antibiotic Resistance (MAR)	1.) Rapid. 2.) Can be used to discriminate between multiple animal sources.	1.) Requires reference database. 2.) May be geographically specific. 3.) Isolates that show no antibiotic resistance cannot be typed.
Pulse-field Gel Electrophoresis (PFGE)	1.) Extremely sensitive to minute genetic differences.	1.) May be too sensitive to broadly discriminate for source tracking.
Polymerase Chain Reaction (PCR)	1.) Rapid & easy to perform.	1.) Trouble with reproducibility. 2.) Requires reference database. 3.) May be geographically specific.
Ribotyping	1.) Highly reproducible. 2.) Can be useful in classifying isolates from multiple sources.	1.) Labor intensive. 2.) Requires reference database. 3.) May be geographically specific. 4.) Laboratory specific variations in methods may cause problems.

Table 1. Pros and Cons of Existing Microbial Source Tracking Methods Cont.

Host-specific Molecular Markers (*Bacteroides-Prevotella*)	1.) No culturing of organism required. 2.) PCR method is rapid and easy to perform.	1.) Environmental survival & distribution still poorly understood. 2.) Method not yet applicable to all animals.
Caffeine	1.) May be useful for assessing impacts from human sewage.	1.) Method sensitivity and background levels are an issue. 2.) Analysis may be expensive.
Fecal sterols/stanols	1.) Specificity for humans and animals may vary greatly for some sterols/stanols.	1.) Naturally present in many sediments. 2.) Method sensitivity and background levels are an issue. 3.) Analysis may be expensive.

BLS

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August 18, 2004

Mr. Brett Stevens
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Central Valley Regional Water Quality Control Board
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REVISIONS TO CITY OF STOCKTON PATHOGEN PLAN

Pursuant to your June 29, 2004 comment letter regarding the April 2004 Pathogen Plan, the City of Stockton hereby submits revisions to the subject Pathogen Plan. The proposed revisions were developed in conjunction with the County of San Joaquin. As agreed upon in your recent discussion with Mr. Malcolm Walker of Larry Walker Associates, Inc., we are submitting this letter as a formal modification to the Plan in lieu of submitting a revised Pathogen Plan. The modifications to the Plan are reflected in our response to your specific comments noted below.

Response #1 – Implementation of BMPs before Pathogen Plan Begins

- *"While we agree with the Permittees' methodical procedure of investigating the pathogen sources and developing appropriate BMPs, it is clear there are some BMPs that the Permittees can implement in the short-term to ameliorate the pathogen problem. For example, Section 2.4.5 on Page 22 discusses the Permittees' current activities for controlling pathogen contributions from domestic pet wastes. One BMP is ensuring that the animal holding areas of the Permittees' pounds are plumbed to the sanitary sewer. These facilities are periodically washed down and the rinse water contains pet waste. Private kennels share these same conditions. Since the Permittees' MS4 permit requires inspection of kennels, these inspections should ensure that any rinse water being generated is properly managed. Additionally, Page 23 states that "pet waste bags have been made available at some parks." This is an inadequate description of this worthwhile BMP. Have you designated some threshold of dog walker traffic to justify dog waste disposal stations? Have you installed stations as quickly as practicable and developed a schedule for station installation? The plan should identify BMPs such as these that the Permittees intend to implement in the short-term and concurrently with the ongoing studies. You certainly know more about your municipalities than we do. Perhaps you can think of a few more BMPs (either new or improvements to existing ones) that fall into this category."*

Stockton
All-America City
1999

In response to the Regional Board's comment the City offer the following information.

- The City's animal shelter is primarily housed indoors and on the premises of the Corporation Yard. However, some of the cages are outside, exposed to the rain. Additionally, each day the staff washes and cleans these cages, and the runoff goes to storm drain serving the Corporation Yard. This storm drain is connected to the sanitary system.

- The City has scheduled to inspect private kennels prior to the end of this year as part of commercial facilities inspection required by NPDES permit. We will ensure that the Evaluation Checklist addresses the plumbing of rinse water into sanitary sewer and provide the needed public outreach and education materials during inspection.

- There are currently 59 parks within the City of Stockton. Of those, six parks - Sherwood, Atherton, Legion, Grupe, Weston and Shropshire - have pet waste bag dispensing stations (PWBDS). The location of stations in each park was established based on visual inspection and dog walker traffic by the landscape maintenance crews who mow the lawns. However, in spite of these dispensing stations, some parks were observed to have a large amount of pet poop remaining on the lawn.

  Before the end of this calendar year, the City will complete five more parks - Nelson, Long Equinoa, Garrigan and Baxter. All of those parks will have PWBDS. In addition, the City will construct a bark park in Weston Park, which will also have an additional waste disposal station. That will leave 49 parks without the PWBDS. The Parks & Recreation Department plans to have these stations installed at all new parks.

  The cost of each PWBDS is about $250, for an approximate total cost of $12,250 for installation in all remaining parks. Park & Recreation Department is planning to allocate budget for the construction of dispensing stations for four to five parks each year for the next 10 years. In an effort to accelerate the time schedule the City is currently exploring other funding opportunities including cost sharing with local pet stores/kennels and using stormwater management program to underwrite the expenses.

- Proper disposal is currently addressed in our existing outreach material, i.e., as part of the school program presentation, school activity booklets, stormwater video, P2 brochures, theater ads, city-wide mailers, included in community event demonstrations, monthly City utility bill, newspaper ads, etc. In addition the City will develop a specific fact sheet on pet waste to be distributed in local pet stores, kennels, pet sitting services, etc. The City is also looking at opportunities for being present at local pet events including: Stockton Animal Shelter Friends – Strut Your Mutt (Sept. 18) and the Delta Humane Society & S.P.C.A. - Doggie Dash (Oct. 2).

- And finally the City is looking at purchasing scooper waste bags for pet owners. Such a product would include the stormwater logo, slogan – "Only Rain Down the Drain" and the stormwater hotline number for illegal dumping. The product could be distributed at

community events. It may also be possible to have local pet stores, kennels, pet sitting services, etc., and underwrite the cost of the bags in exchange for some type of advertising on the bag.

Response # 2 – Location of Monitoring Stations/Sites

- *"Page34 states that bacteria monitoring will be conducted at strategic locations; however, the plan doesn't appear to provide the criteria for selecting these locations. The number of outfalls that will be monitored for a given water body is provided; but how many outfalls are there for each water body? What are the drainage areas for monitored outfalls and unmonitored outfalls? What are the land uses for monitored outfalls and unmonitored outfalls? Are some outfalls inaccessible for sampling? Since selection of sampling locations is so critical, this information should be presented in the plan."*

Site Selection Criteria

Smith Canal and Five Mile Slough receive storm water runoff only from the Stockton Urbanized Area. Additionally, the Calaveras River, Mosher Slough, and Walker Slough receive storm water runoff from agricultural areas upstream of the Stockton Urbanized Area. All of these water bodies discharge to the San Joaquin River and are tidally influenced. In most areas of the Stockton Urbanized Area, dry weather flow and storm water runoff are also released to the sloughs and rivers. The quality and quantity of these discharges vary considerably and are affected by hydrology, geology, land use activities, season, and sequence and duration of hydrologic events. Previous urban runoff studies show "typical" sources of bacteria include urban litter, contaminated refuse, domestic pet and wildlife excrement, and failing sewer lines. It is also well known that fecal bacteria densities are directly related to the density of housing, population, development, percent impervious area, and the density of domestic animals. Additionally, recreational areas and areas frequented by the homeless often have high bacteria counts.

With these watershed and hydrologic characteristics in mind, the City and County used the following criteria in selecting the monitoring sites:

- Representative land use and activities. A cross section of land uses and land uses representative of the subwatershed were chosen.
- Site access. Ability of accessing a sample site was considered.
- Sites should be spatially representative of the water body (e.g. sites present at both the upper and lower ends of the water body).
- Sites should overlap with ongoing and/or proposed studies whenever possible (e.g. Smith Canal dissolved oxygen study).
- Monitoring crew safety.

Number of Outfalls per Waterbody

Waterbody	City	County	Private	State
Five Mile Creek	11		-	-
Calaveras River	8	4	-	-

Mormon Slough	19		5	2
Mosher Slough	13	3	-	-
Smith Canal	6	4	-	-
Walker Slough/Duck Creek	7		-	-

Drainage Areas (in acres) of Monitored and Unmonitored Outfalls (Smith Canal and Mormon Slough only – monitored outfalls highlighted in bold red type)

Smith Canal		
City Outfalls		
SC-102 (SC4-D)[1]	**Smith Canal 102**	**5.61**
SC-103	Smith Canal 103	7.87
SC-104	Smith Canal 104	16.99
SC-55 (SC3-D)	**Ryde and Smith Canal P.S.**	**196.90**
SC-56 (SC2-D)	**Buena Vista & Smith Canal P.S.**	**488.49**
SC-57 (SC1-D)	**Legion Park & Smith Canal P.S.**	**1862.27**
County Outfalls		
SC-1	Country Club at Franklin	123.52
SC-2	Lake Drive at Tuxedo	229.20
SC-3	Buena Vista and Middlefield	57.91
SC-7	Moering Ave.	56.79
Mormon Slough		
City Outfalls		
MM-140	Mormon Slough 140	31.25
MM-141 (MR3-D)	**Mormon Slough 141**	**72.8**
MM-142	Mormon Slough 142	431.33
MM-143	Mormon Slough 143	19.55
MM-144	Mormon Slough 144	21.43
MM-145	Mormon Slough 145	19.61
MM-147	Mormon Slough 147	142.45
MM-148	Mormon Slough 148	7.42
MM-149	Mormon Slough 149	6.28
MM-150 (MR2-D)	**Mormon Slough 150**	**955.46**
MM-151	Mormon Slough 151	118.12
MM-152	Mormon Slough 152	15.41
MM-153	Mormon Slough 153	77.32
MM-154	Mormon Slough 154	298.15
MM-155	Mormon Slough 155	279.56
MM-157	Mormon Slough 157	143.57
MM-158	Mormon Slough 158	32.69
MM-159	Mormon Slough 159	351.29
MM-162	Mormon Slough 162	1.41
Private Outfalls		
P-6	Private outfall	11.23

P-7	Private outfall	8.84
P-8	Private outfall	5.41
P-9	Private outfall	24.65

1 Nomenclature shown in parenthesis reflects sample location designation noted in Pathogen Plan.

Land Uses for Smith Canal and Mormon Slough Drainage Basins (in acres)

Land Use	Smith Canal	Mormon Slough
Low-Med Density Residential	2410	1300
High Density Residential	130	75
Admin-Professional	85	25
Commercial	200	395
Institutional	220	215
Parks and Recreation	12	215
Performance Industrial	15	-
Industrial	240	1075
Total	3312 acres	3085 acres

Land Uses for Monitored Outfalls (in percentages)

Land Use	SC-102	SC-55	SC-56	SC-57	MM-141	MM-150
Low-Med Density Residential	0	63	85	67	0	35
High Density Residential	88	1	0	2	0	5
Admin-Professional	0	0	2	4	0	0
Commercial	0	0	0	10	0	20
Institutional	0	0	0	10	0	14
Parks and Recreation	12	2	1	0	0	0
Performance Industrial	0	5	0	0	0	0
Industrial	0	29	12	6	100	26
Unaccounted	0	0	0	1	0	0
Total	100	100	100	100	100	100

A summary of the land uses for all outfalls within the City of Stockton is shown in Attachment A. In addition watershed maps for Mormon Slough and Smith Canal are shown in Attachment B. These maps identify the locations of the monitoring stations and land uses within the watersheds.

Accessibility of Outfalls

No outfalls are considered inaccessible. However, there may be occasions when sampling locations may be inaccessible due to high water levels. All of the waterbodies described in the Pathogen Plan are tidally influenced and some sites may be inaccessible during high tides.

Therefore, for some sites, some allowance may have to be made for synchronizing sampling efforts with low tides.

Response #3 – How to Distinguish between Sources of Bacteria and Determine their Relative Significance

- *"Page 36 presents the two approaches of source identification studies: Location tracking and microbial source tracking. While these studies should certainly be designed to detect undiscovered pathogen sources, another goal should be to determine the contributions and relative significance of suspected sources (as listed on Page 27). We believe the plan should therefore include a discussion of how the two source ID studies can distinguish between suspected sources and determine their relative significance. This issue seems implicit in the description of the source ID studies; however, a more explicit discussion would better explain the Permittees' intent."*

Microbial source tracking (MST) is an evolving watershed management tool for the assessment of various inputs of fecal microorganisms into surface and groundwater from point source and non-point source runoff. Once fully implemented, a successful MST program should allow one to differentiate between human and non-human sources of bacteria and for identifying likely contributors of fecal contamination. Ideally, the methods in use should also give a quantitative estimate of the impact of various sources of contamination to facilitate risk management. At this time, MST is still limited by the rate of progress of academic microbiological and molecular research necessary to provide a reproducible and reliable methodology for use in the decision-making process as it relates to watershed protection. One of the most promising methods has been developed is the *Bacteroides-Prevotella* TFRLP method. The assay involves a polymerase chain reaction (PCR) procedure based on the host-specific detection of marker genes in the bacterial *Bacteroides-Prevotella* group, which is numerically more abundant in feces than are coliforms. With this procedure it is possible to distinguish between human and non-human fecal sources as well as differentiate between non-human sources (cattle, dog, etc.). The Pathogen Plan intends to make use of this technique to pinpoint and identify sources of bacterial pollution. However, because of the relatively high costs of sample processing and the specialized equipment needed to undertake sample collection, it is first necessary to "zero in" on locations that are known to be contributing high concentrations of bacteria to a waterbody. As outlined in the Pathogen Plan, this is a three-step process:

1. Characterization Monitoring: Identifies large-scale spatial and temporal trends in bacteria concentrations within the waterbody (delineates subwatersheds that are problematic).
2. Location Tracking Studies: Pinpoints locations within a subwatershed that discharges high levels of bacteria.
3. Microbial Source Tracking Studies: Identifies the source of the bacteria (dog, human, etc.) using recombinant DNA technology.

Characterization Monitoring will be used to identify and verify spatial trends or patterns and the magnitude of bacterial contamination at a large scale within the watershed. These spatial data are expected to provide insight into the location and movement patterns of indicator bacteria. Once

large-scale spatial patterns have been identified, Location Tracking Studies is employed to determine which particular area or point within a sub-watershed is a likely substantial source of bacteria. Once locations have been pinpointed, MST techniques can be employed to verify and qualify the sources of the bacteria. This information can be qualified such that the City and County can determine what proportion of the bacterial load is attributable to humans, dogs, etc. This information will in turn allow the City and County to employ appropriate BMPs, in a cost effective manner, to reduce the amount of bacteria released from the identified sources. For instance, a high proportion of human *Bacteroides* may indicate a leaking sewer while a high proportion of dog *Bacteroides* may indicate that dog feces are not being properly disposed of. Either outcome would require the deployment of different BMPs to reduce bacterial discharges.

Response #4 – Reporting Format

- *"Section 4.6 is vague on what deliverables the Regional Board can expect. We presume the annual reports will contain updates on the progress of the pathogen studies. We'd prefer a final report broken out for each water body upon completion of its study; these final reports could be appendices to the annual reports. The plan should be revised to specify the Permittees' intent with regard to reporting."*

The City and County will prepare annual progress reports regarding the Pathogen Plan implementation that will be included as part of the City and County Annual Stormwater Management Program Reports. The progress reports will contain tabular and graphical summaries, as appropriate, of the various monitoring and source tracking efforts. In addition, the City and County will prepare final reports for each water body upon completion of the study.

The City and County trusts that this letter response addresses your concerns and provided further clarification of our efforts to implement the Pathogen Plan. Please feel free to contact the undersigned if you have any questions or comments.

MARK J. MADISON, P.E.
DIRECTOR OF MUNICIPAL UTILITIES

ROBERT K. MURDOCH, P.E.
ASSISTANT DIRECTOR OF MUNICIPAL UTILITIES

RM:AK

Attachments

cc: Chuck Kelly, San Joaquin County
Amin Kazemi, City of Stockton
Mack Walker, Larry Walker Associates, Inc.

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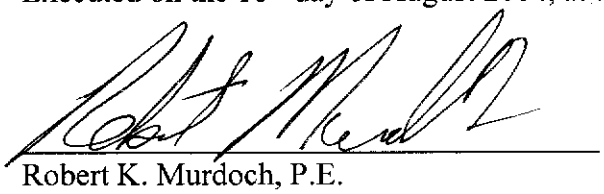
CERTIFICATION

I certify under the penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted.

Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility, of a fine and imprisonment for knowing violations.

Executed on the 18th day of August 2004, at the City of Stockton.



Robert K. Murdoch, P.E.
Assistant Director of Municipal Utilities

Attachment A

Outfalls Land Uses Summary

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
5 MILE CREEK 118	1.06028609963	1.06028609963	LOW-MEDIUM RESIDENTIAL	100%
5 MILE CREEK 119	9.25311782599	8.50763233406	LOW-MEDIUM RESIDENTIAL	92%
5 MILE CREEK 119	9.25311782599	0.74548549193	COMMERCIAL	8%
5 MILE CREEK 129	22.96012109730	21.67701844690	LOW-MEDIUM RESIDENTIAL	94%
5 MILE CREEK 129	22.96012109730	0.22162238847	HIGH DENSITY RESIDENTIAL	1%
5 MILE CREEK 129	22.96012109730	1.06148026198	COMMERCIAL	5%
5 MILE CREEK 134	13.73486713730	11.11209682050	LOW-MEDIUM RESIDENTIAL	81%
5 MILE CREEK 134	13.73486713730	0.31037838045	HIGH DENSITY RESIDENTIAL	2%
5 MILE CREEK 134	13.73486713730	2.31239193635	COMMERCIAL	17%
5 MILE CREEK 135	3.00086949036	0.00704883103	LOW-MEDIUM RESIDENTIAL	0%
5 MILE CREEK 135	3.00086949036	2.99382065933	COMMERCIAL	100%
5 MILE CREEK 164	11.01317435720	11.01317435720	LOW-MEDIUM RESIDENTIAL	100%
AIRPORT & DUCK CREEK P.S.	324.63936524300	3.13176017137	NOT APPLICABLE/UNKOWN	1%
AIRPORT & DUCK CREEK P.S.	324.63936524300	317.53126624200	LOW-MEDIUM RESIDENTIAL	98%
AIRPORT & DUCK CREEK P.S.	324.63936524300	0.00070739544	HIGH DENSITY RESIDENTIAL	0%
AIRPORT & DUCK CREEK P.S.	324.63936524300	1.50461791081	COMMERCIAL	0%
AIRPORT & DUCK CREEK P.S.	324.63936524300	0.10106875393	PERFORMANCE INDUSTRIAL	0%
AIRPORT & DUCK CREEK P.S.	324.63936524300	0.00372196175	INDUSTRIAL	0%
AIRPORT & DUCK CREEK P.S.	324.63936524300	2.36621563418	INSTITUTIONAL	1%
AIRPORT GATEWAY P.S.	496.79981634500	5.78297902627	NOT APPLICABLE/UNKOWN	1%
AIRPORT GATEWAY P.S.	496.79981634500	475.81762594300	INDUSTRIAL	96%
AIRPORT GATEWAY P.S.	496.79981634500	15.19923289750	INSTITUTIONAL	3%
ALEXANDRIA & 14 MILE SLOUGH P.S.	729.12075298400	0.00000256642	NOT APPLICABLE/UNKOWN	0%
ALEXANDRIA & 14 MILE SLOUGH P.S.	729.12075298400	511.19211464000	LOW-MEDIUM RESIDENTIAL	70%
ALEXANDRIA & 14 MILE SLOUGH P.S.	729.12075298400	49.99059562740	HIGH DENSITY RESIDENTIAL	7%
ALEXANDRIA & 14 MILE SLOUGH P.S.	729.12075298400	49.47329124340	ADMINISTRATIVE PROFESSIONAL	7%
ALEXANDRIA & 14 MILE SLOUGH P.S.	729.12075298400	116.60547693500	COMMERCIAL	16%
ALEXANDRIA & 14 MILE SLOUGH P.S.	729.12075298400	1.85926049335	INSTITUTIONAL	0%
ALEXANDRIA & 5 MILE CREEK P.S.	147.41873278200	141.96127927800	LOW-MEDIUM RESIDENTIAL	96%
ALEXANDRIA & 5 MILE CREEK P.S.	147.41873278200	5.45745637413	PARKS AND RECREATION	4%
ARCH ROAD INDUSTRIAL PARK P.S.	218.83181818200	0.25202788347	NOT APPLICABLE/UNKOWN	0%
ARCH ROAD INDUSTRIAL PARK P.S.	218.83181818200	54.41050139180	COMMERCIAL	25%
ARCH ROAD INDUSTRIAL PARK P.S.	218.83181818200	152.63470133200	INDUSTRIAL	70%
ARCH ROAD INDUSTRIAL PARK P.S.	218.83181818200	0.21555739889	INSTITUTIONAL	0%
ARCH ROAD INDUSTRIAL PARK P.S.	218.83181818200	11.31902300210	AGRICULTURE	5%
ARCH-AIRPORT DRAIN 169	6.80814680900	0.54789809901	INDUSTRIAL	8%
ARCH-AIRPORT DRAIN 169	6.80814680900	6.26024870999	INSTITUTIONAL	92%
ARCH-AIRPORT DRAIN 170	16.64756800960	16.64756800960	INSTITUTIONAL	100%
BAINBRIDGE & MOSHER SLOUGH P.S.	103.66601239700	0.05866023222	NOT APPLICABLE/UNKOWN	0%
BAINBRIDGE & MOSHER SLOUGH P.S.	103.66601239700	103.60734929500	LOW-MEDIUM RESIDENTIAL	100%
BIANCHI & CALAVERAS RIVER P.S.	843.64747474700	509.07660160400	LOW-MEDIUM RESIDENTIAL	60%

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
BIANCHI & CALAVERAS RIVER P.S.	843.64747474700	147.10315187700	HIGH DENSITY RESIDENTIAL	17%
BIANCHI & CALAVERAS RIVER P.S.	843.64747474700	32.63735530350	ADMINISTRATIVE PROFESSIONAL	4%
BIANCHI & CALAVERAS RIVER P.S.	843.64747474700	154.37193589200	COMMERCIAL	18%
BIANCHI & CALAVERAS RIVER P.S.	843.64747474700	0.45801190180	PERFORMANCE INDUSTRIAL	0%
BIANCHI & CALAVERAS RIVER P.S.	843.64747474700	0.00038086378	INSTITUTIONAL	0%
BLACK OAK & 14 MILE SLOUGH P.S.	598.79081726400	312.10667360000	LOW-MEDIUM RESIDENTIAL	52%
BLACK OAK & 14 MILE SLOUGH P.S.	598.79081726400	39.64540783090	HIGH DENSITY RESIDENTIAL	7%
BLACK OAK & 14 MILE SLOUGH P.S.	598.79081726400	31.73211737950	ADMINISTRATIVE PROFESSIONAL	5%
BLACK OAK & 14 MILE SLOUGH P.S.	598.79081726400	48.98397347860	COMMERCIAL	8%
BLACK OAK & 14 MILE SLOUGH P.S.	598.79081726400	166.32262632200	INSTITUTIONAL	28%
BROOKSIDE & CALAVERAS RIVER P.S.	310.07486225900	1.43245495015	NOT APPLICABLE/UNKOWN	0%
BROOKSIDE & CALAVERAS RIVER P.S.	310.07486225900	117.50127205900	LOW-MEDIUM RESIDENTIAL	38%
BROOKSIDE & CALAVERAS RIVER P.S.	310.07486225900	63.63246064420	HIGH DENSITY RESIDENTIAL	21%
BROOKSIDE & CALAVERAS RIVER P.S.	310.07486225900	46.14528617530	ADMINISTRATIVE PROFESSIONAL	15%
BROOKSIDE & CALAVERAS RIVER P.S.	310.07486225900	38.09183775450	COMMERCIAL	12%
BROOKSIDE & CALAVERAS RIVER P.S.	310.07486225900	43.27155354520	INSTITUTIONAL	14%
BROOKSIDE & I-5 P.S.	408.34485766800	0.56886507697	NOT APPLICABLE/UNKOWN	0%
BROOKSIDE & I-5 P.S.	408.34485766800	271.05538500000	LOW-MEDIUM RESIDENTIAL	66%
BROOKSIDE & I-5 P.S.	408.34485766800	31.19537024850	HIGH DENSITY RESIDENTIAL	8%
BROOKSIDE & I-5 P.S.	408.34485766800	31.54429209780	ADMINISTRATIVE PROFESSIONAL	8%
BROOKSIDE & I-5 P.S.	408.34485766800	66.27169492360	COMMERCIAL	16%
BROOKSIDE & I-5 P.S.	408.34485766800	7.70924171235	INSTITUTIONAL	2%
BROOKSIDE ESTATES (NORTH) P.S.	901.84462809900	0.31574963618	NOT APPLICABLE/UNKOWN	0%
BROOKSIDE ESTATES (NORTH) P.S.	901.84462809900	765.05057667000	LOW-MEDIUM RESIDENTIAL	85%
BROOKSIDE ESTATES (NORTH) P.S.	901.84462809900	38.72339918070	HIGH DENSITY RESIDENTIAL	4%
BROOKSIDE ESTATES (NORTH) P.S.	901.84462809900	69.11609399980	ADMINISTRATIVE PROFESSIONAL	8%
BROOKSIDE ESTATES (NORTH) P.S.	901.84462809900	28.23549272880	COMMERCIAL	3%
BROOKSIDE ESTATES (NORTH) P.S.	901.84462809900	0.00383293332	INSTITUTIONAL	0%
BROOKSIDE ESTATES (NORTH) P.S.	901.84462809900	0.39944277605	PARKS AND RECREATION	0%
BROOKSIDE ESTATES (SOUTH) P.S.	296.96678145100	0.00002357626	NOT APPLICABLE/UNKOWN	0%
BROOKSIDE ESTATES (SOUTH) P.S.	296.96678145100	296.96675357000	LOW-MEDIUM RESIDENTIAL	100%
BUENA VISTA & SMITH CANAL P.S.	488.48801652900	0.00141707207	NOT APPLICABLE/UNKOWN	0%
BUENA VISTA & SMITH CANAL P.S.	488.48801652900	416.51155042300	LOW-MEDIUM RESIDENTIAL	85%
BUENA VISTA & SMITH CANAL P.S.	488.48801652900	7.82641785914	ADMINISTRATIVE PROFESSIONAL	2%
BUENA VISTA & SMITH CANAL P.S.	488.48801652900	1.01952665839	COMMERCIAL	0%
BUENA VISTA & SMITH CANAL P.S.	488.48801652900	58.71721232660	INDUSTRIAL	12%
BUENA VISTA & SMITH CANAL P.S.	488.48801652900	4.41188931976	PARKS AND RECREATION	1%
CAYUGA & MOSHER SLOUGH P.S.	739.25433884300	3.18988815921	NOT APPLICABLE/UNKOWN	0%
CAYUGA & MOSHER SLOUGH P.S.	739.25433884300	512.61612766900	LOW-MEDIUM RESIDENTIAL	69%
CAYUGA & MOSHER SLOUGH P.S.	739.25433884300	37.92072263220	HIGH DENSITY RESIDENTIAL	5%
CAYUGA & MOSHER SLOUGH P.S.	739.25433884300	17.90674124730	ADMINISTRATIVE PROFESSIONAL	2%
CAYUGA & MOSHER SLOUGH P.S.	739.25433884300	127.67181806700	COMMERCIAL	17%
CAYUGA & MOSHER SLOUGH P.S.	739.25433884300	39.94906116180	PERFORMANCE INDUSTRIAL	5%
CHERBOURG & MOSHER SLOUGH P.S.	1186.02988981000	3.80503013478	NOT APPLICABLE/UNKOWN	0%
CHERBOURG & MOSHER SLOUGH P.S.	1186.02988981000	865.27132747900	LOW-MEDIUM RESIDENTIAL	73%
CHERBOURG & MOSHER SLOUGH P.S.	1186.02988981000	4.72821833069	HIGH DENSITY RESIDENTIAL	0%
CHERBOURG & MOSHER SLOUGH P.S.	1186.02988981000	5.41247825915	ADMINISTRATIVE PROFESSIONAL	0%

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
CHERBOURG & MOSHER SLOUGH P.S.	1186.02988981000	224.49038127300	COMMERCIAL	19%
CHERBOURG & MOSHER SLOUGH P.S.	1186.02988981000	32.29680282340	PERFORMANCE INDUSTRIAL	3%
CHERBOURG & MOSHER SLOUGH P.S.	1186.02988981000	50.02562424570	INDUSTRIAL	4%
CLAYTON & HARVEY P.S.	67.14140266300	1.08366467269	NOT APPLICABLE/UNKOWN	2%
CLAYTON & HARVEY P.S.	67.14140266300	50.57487334730	LOW-MEDIUM RESIDENTIAL	75%
CLAYTON & HARVEY P.S.	67.14140266300	11.83625067580	COMMERCIAL	18%
CLAYTON & HARVEY P.S.	67.14140266300	3.64661253238	INDUSTRIAL	5%
COUNTY	2512.45848112000	2.78718577088	NOT APPLICABLE/UNKOWN	0%
COUNTY	2512.45848112000	2304.86812708000	LOW-MEDIUM RESIDENTIAL	92%
COUNTY	2512.45848112000	99.12538229690	HIGH DENSITY RESIDENTIAL	4%
COUNTY	2512.45848112000	0.00100463850	ADMINISTRATIVE PROFESSIONAL	0%
COUNTY	2512.45848112000	77.47722701030	COMMERCIAL	3%
COUNTY	2512.45848112000	1.36991405709	INDUSTRIAL	0%
COUNTY	2512.45848112000	21.66470329180	INSTITUTIONAL	1%
COUNTY	2512.45848112000	5.16496710671	PARKS AND RECREATION	0%
DEEP WATER CHANNEL 101	0.25292412764	0.00012319871	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 101	0.25292412764	0.25280092893	PARKS AND RECREATION	100%
DEEP WATER CHANNEL 108	3.01741706841	0.00004687493	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 108	3.01741706841	2.52370069407	INDUSTRIAL	84%
DEEP WATER CHANNEL 108	3.01741706841	0.49366949942	PARKS AND RECREATION	16%
DEEP WATER CHANNEL 111	6.63156565657	0.00015737519	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 111	6.63156565657	6.24708004306	COMMERCIAL	94%
DEEP WATER CHANNEL 111	6.63156565657	0.38432823833	PARKS AND RECREATION	6%
DEEP WATER CHANNEL 112	73.54477731860	59.95395556780	LOW-MEDIUM RESIDENTIAL	82%
DEEP WATER CHANNEL 112	73.54477731860	7.46900590382	ADMINISTRATIVE PROFESSIONAL	10%
DEEP WATER CHANNEL 112	73.54477731860	6.12164433810	COMMERCIAL	8%
DEEP WATER CHANNEL 112	73.54477731860	0.00016863935	PARKS AND RECREATION	0%
DEEP WATER CHANNEL 113	17.49334538570	0.00011767360	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 113	17.49334538570	2.91822145658	LOW-MEDIUM RESIDENTIAL	17%
DEEP WATER CHANNEL 113	17.49334538570	13.95695582720	ADMINISTRATIVE PROFESSIONAL	80%
DEEP WATER CHANNEL 113	17.49334538570	0.61805042829	PARKS AND RECREATION	4%
DEEP WATER CHANNEL 114	0.26482724977	0.00010270333	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 114	0.26482724977	0.26472454644	PARKS AND RECREATION	100%
DEEP WATER CHANNEL 115	86.42076446280	0.00038092317	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 115	86.42076446280	64.66883470790	LOW-MEDIUM RESIDENTIAL	75%
DEEP WATER CHANNEL 115	86.42076446280	6.18662945603	HIGH DENSITY RESIDENTIAL	7%
DEEP WATER CHANNEL 115	86.42076446280	10.03612872870	ADMINISTRATIVE PROFESSIONAL	12%
DEEP WATER CHANNEL 115	86.42076446280	5.17961378674	COMMERCIAL	6%
DEEP WATER CHANNEL 115	86.42076446280	0.34917542545	PARKS AND RECREATION	0%
DEEP WATER CHANNEL 116	17.69813045220	0.00015525034	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 116	17.69813045220	1.57887542586	LOW-MEDIUM RESIDENTIAL	9%
DEEP WATER CHANNEL 116	17.69813045220	3.20572762065	HIGH DENSITY RESIDENTIAL	18%
DEEP WATER CHANNEL 116	17.69813045220	12.25325862550	COMMERCIAL	69%
DEEP WATER CHANNEL 116	17.69813045220	0.66011352995	PARKS AND RECREATION	4%

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
DEEP WATER CHANNEL 117	7.00533890037	0.00021739304	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 117	7.00533890037	6.52330705105	COMMERCIAL	93%
DEEP WATER CHANNEL 117	7.00533890037	0.48181445629	PARKS AND RECREATION	7%
DEEP WATER CHANNEL 120	119.94857667600	0.00001619815	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 120	119.94857667600	25.36641004110	LOW-MEDIUM RESIDENTIAL	21%
DEEP WATER CHANNEL 120	119.94857667600	21.86675004530	HIGH DENSITY RESIDENTIAL	18%
DEEP WATER CHANNEL 120	119.94857667600	31.12722010450	ADMINISTRATIVE PROFESSIONAL	26%
DEEP WATER CHANNEL 120	119.94857667600	37.64237023150	COMMERCIAL	31%
DEEP WATER CHANNEL 120	119.94857667600	3.76991733150	INSTITUTIONAL	3%
DEEP WATER CHANNEL 120	119.94857667600	0.17589415630	PARKS AND RECREATION	0%
DEEP WATER CHANNEL 121	57.52287075300	0.00004028776	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 121	57.52287075300	6.70149235146	HIGH DENSITY RESIDENTIAL	12%
DEEP WATER CHANNEL 121	57.52287075300	1.29595584761	ADMINISTRATIVE PROFESSIONAL	2%
DEEP WATER CHANNEL 121	57.52287075300	39.83247204920	COMMERCIAL	69%
DEEP WATER CHANNEL 121	57.52287075300	9.56748659620	INSTITUTIONAL	17%
DEEP WATER CHANNEL 121	57.52287075300	0.12542218592	PARKS AND RECREATION	0%
DEEP WATER CHANNEL 122	2.33590593434	0.00006810643	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 122	2.33590593434	2.27309904796	INSTITUTIONAL	97%
DEEP WATER CHANNEL 122	2.33590593434	0.06273877995	PARKS AND RECREATION	3%
DEEP WATER CHANNEL 123	1119.72626263000	0.00008165400	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 123	1119.72626263000	425.70868773700	LOW-MEDIUM RESIDENTIAL	38%
DEEP WATER CHANNEL 123	1119.72626263000	52.69647615430	HIGH DENSITY RESIDENTIAL	5%
DEEP WATER CHANNEL 123	1119.72626263000	294.03463273500	COMMERCIAL	26%
DEEP WATER CHANNEL 123	1119.72626263000	10.63954671850	PERFORMANCE INDUSTRIAL	1%
DEEP WATER CHANNEL 123	1119.72626263000	278.32064080500	INDUSTRIAL	25%
DEEP WATER CHANNEL 123	1119.72626263000	57.30956768140	INSTITUTIONAL	5%
DEEP WATER CHANNEL 123	1119.72626263000	1.01661622740	PARKS AND RECREATION	0%
DEEP WATER CHANNEL 126	0.70181072085	0.16671262299	COMMERCIAL	24%
DEEP WATER CHANNEL 126	0.70181072085	0.53509809785	PARKS AND RECREATION	76%
DEEP WATER CHANNEL 127	51.07626693070	50.84121573530	COMMERCIAL	100%
DEEP WATER CHANNEL 127	51.07626693070	0.23505119539	PARKS AND RECREATION	0%
DEEP WATER CHANNEL 128	4.41599948347	4.34208364208	COMMERCIAL	98%
DEEP WATER CHANNEL 128	4.41599948347	0.07391584140	PARKS AND RECREATION	2%
DEEP WATER CHANNEL 130	1.67602588384	1.55276923668	COMMERCIAL	93%
DEEP WATER CHANNEL 130	1.67602588384	0.12325664716	PARKS AND RECREATION	7%
DEEP WATER CHANNEL 131	14.74105400600	0.00014262313	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 131	14.74105400600	14.74091138280	COMMERCIAL	100%
DEEP WATER CHANNEL 133	0.19356921488	0.00023990068	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 133	0.19356921488	0.16616840190	INSTITUTIONAL	86%
DEEP WATER CHANNEL 133	0.19356921488	0.02716091229	PARKS AND RECREATION	14%
DEEP WATER CHANNEL 138	33.52000114780	0.00222764645	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 138	33.52000114780	17.42247216110	LOW-MEDIUM RESIDENTIAL	52%
DEEP WATER CHANNEL 138	33.52000114780	2.39523763146	ADMINISTRATIVE PROFESSIONAL	7%
DEEP WATER CHANNEL 138	33.52000114780	13.03885325060	COMMERCIAL	39%

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
DEEP WATER CHANNEL 138	33.52000114780	0.66120902344	PARKS AND RECREATION	2%
DEEP WATER CHANNEL 139	10.61483872820	0.00039948030	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 139	10.61483872820	9.36202274967	COMMERCIAL	88%
DEEP WATER CHANNEL 139	10.61483872820	1.10545811919	INSTITUTIONAL	10%
DEEP WATER CHANNEL 139	10.61483872820	0.14695837903	PARKS AND RECREATION	1%
DEEP WATER CHANNEL 156	12.85434314740	0.31097237936	NOT APPLICABLE/UNKOWN	2%
DEEP WATER CHANNEL 156	12.85434314740	8.29807127309	HIGH DENSITY RESIDENTIAL	65%
DEEP WATER CHANNEL 156	12.85434314740	4.24529949492	COMMERCIAL	33%
DEEP WATER CHANNEL 163	0.24134814050	0.00026076034	NOT APPLICABLE/UNKOWN	0%
DEEP WATER CHANNEL 163	0.24134814050	0.24108738015	PARKS AND RECREATION	100%
DON & MOSHER SLOUGH P.S.	389.47685950400	1.50601951234	NOT APPLICABLE/UNKOWN	0%
DON & MOSHER SLOUGH P.S.	389.47685950400	351.99943686200	LOW-MEDIUM RESIDENTIAL	90%
DON & MOSHER SLOUGH P.S.	389.47685950400	11.47563629710	HIGH DENSITY RESIDENTIAL	3%
DON & MOSHER SLOUGH P.S.	389.47685950400	24.49574961490	COMMERCIAL	6%
DUCK CREEK 165	419.36620753000	4.30038332042	NOT APPLICABLE/UNKOWN	1%
DUCK CREEK 165	419.36620753000	98.37431910210	LOW-MEDIUM RESIDENTIAL	23%
DUCK CREEK 165	419.36620753000	8.13414826343	HIGH DENSITY RESIDENTIAL	2%
DUCK CREEK 165	419.36620753000	58.29611521560	COMMERCIAL	14%
DUCK CREEK 165	419.36620753000	224.43432087200	INDUSTRIAL	54%
DUCK CREEK 165	419.36620753000	25.82692362630	INSTITUTIONAL	6%
DUCK CREEK 167	399.11960514200	3.95842084797	NOT APPLICABLE/UNKOWN	1%
DUCK CREEK 167	399.11960514200	374.67401911000	LOW-MEDIUM RESIDENTIAL	94%
DUCK CREEK 167	399.11960514200	20.16820915620	COMMERCIAL	5%
DUCK CREEK 167	399.11960514200	0.31871135948	INDUSTRIAL	0%
DUCK CREEK 167	399.11960514200	0.00022458172	INSTITUTIONAL	0%
EIGHTH STREET & SAN JOAQUIN RIVER P.S.	487.57415059700	0.00015341402	NOT APPLICABLE/UNKOWN	0%
EIGHTH STREET & SAN JOAQUIN RIVER P.S.	487.57415059700	386.47828943000	LOW-MEDIUM RESIDENTIAL	79%
EIGHTH STREET & SAN JOAQUIN RIVER P.S.	487.57415059700	94.61025350230	INDUSTRIAL	19%
EIGHTH STREET & SAN JOAQUIN RIVER P.S.	487.57415059700	6.48547577252	PARKS AND RECREATION	1%
EL DORADO & MOSHER SLOUGH P.S.	520.49540863200	1.58098262333	NOT APPLICABLE/UNKOWN	0%
EL DORADO & MOSHER SLOUGH P.S.	520.49540863200	420.31941721600	LOW-MEDIUM RESIDENTIAL	81%
EL DORADO & MOSHER SLOUGH P.S.	520.49540863200	44.93447252100	HIGH DENSITY RESIDENTIAL	9%
EL DORADO & MOSHER SLOUGH P.S.	520.49540863200	6.30064737054	ADMINISTRATIVE PROFESSIONAL	1%
EL DORADO & MOSHER SLOUGH P.S.	520.49540863200	47.35988172690	COMMERCIAL	9%
FORT DONELSON & 14 MILE SL. P.S.	811.56345270900	0.03751068504	NOT APPLICABLE/UNKOWN	0%
FORT DONELSON & 14 MILE SL. P.S.	811.56345270900	650.81583935200	LOW-MEDIUM RESIDENTIAL	80%
FORT DONELSON & 14 MILE SL. P.S.	811.56345270900	81.43192087600	HIGH DENSITY RESIDENTIAL	10%
FORT DONELSON & 14 MILE SL. P.S.	811.56345270900	5.02495608389	ADMINISTRATIVE PROFESSIONAL	1%
FORT DONELSON & 14 MILE SL. P.S.	811.56345270900	42.76343111150	COMMERCIAL	5%
FORT DONELSON & 14 MILE SL. P.S.	811.56345270900	8.11811151286	PERFORMANCE INDUSTRIAL	1%
FORT DONELSON & 14 MILE SL. P.S.	811.56345270900	23.37164147820	PARKS AND RECREATION	3%
GRUPE BUSINESS PARK P.S.	129.65941230500	0.30496647654	NOT APPLICABLE/UNKOWN	0%
GRUPE BUSINESS PARK P.S.	129.65941230500	15.15544740630	COMMERCIAL	12%
GRUPE BUSINESS PARK P.S.	129.65941230500	103.69837103200	INDUSTRIAL	80%
GRUPE BUSINESS PARK P.S.	129.65941230500	10.50063025970	AGRICULTURE	8%

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
HOLMAN & CALAVERAS RIVER P.S.	549.87653810800	348.31763388300	LOW-MEDIUM RESIDENTIAL	63%
HOLMAN & CALAVERAS RIVER P.S.	549.87653810800	15.74241123550	HIGH DENSITY RESIDENTIAL	3%
HOLMAN & CALAVERAS RIVER P.S.	549.87653810800	185.81649442400	COMMERCIAL	34%
HWY 4 & SAN JOAQUIN RIVER P.S.	355.48321854900	0.00001622431	NOT APPLICABLE/UNKOWN	0%
HWY 4 & SAN JOAQUIN RIVER P.S.	355.48321854900	355.34122298700	INDUSTRIAL	100%
HWY 4 & SAN JOAQUIN RIVER P.S.	355.48321854900	0.14197503306	INSTITUTIONAL	0%
I-5 & 14 MILE SLOUGH P.S.	39.98259297520	0.00019302379	NOT APPLICABLE/UNKOWN	0%
I-5 & 14 MILE SLOUGH P.S.	39.98259297520	0.06280612407	LOW-MEDIUM RESIDENTIAL	0%
I-5 & 14 MILE SLOUGH P.S.	39.98259297520	39.91959382730	INSTITUTIONAL	100%
I-5 & BEAR CREEK P.S.	470.11258034900	3.06734213623	NOT APPLICABLE/UNKOWN	1%
I-5 & BEAR CREEK P.S.	470.11258034900	412.12516787200	LOW-MEDIUM RESIDENTIAL	88%
I-5 & BEAR CREEK P.S.	470.11258034900	12.38069854760	HIGH DENSITY RESIDENTIAL	3%
I-5 & BEAR CREEK P.S.	470.11258034900	9.34444204003	ADMINISTRATIVE PROFESSIONAL	2%
I-5 & BEAR CREEK P.S.	470.11258034900	28.38080337550	COMMERCIAL	6%
I-5 & BEAR CREEK P.S.	470.11258034900	0.00422360172	PARKS AND RECREATION	0%
I-5 & BEAR CREEK P.S.	470.11258034900	2.15350957982	NOT APPLICABLE/UNKOWN	0%
KELLY & MOSHER SLOUGH P.S.	530.33962350800	5.00523475262	NOT APPLICABLE/UNKOWN	1%
KELLY & MOSHER SLOUGH P.S.	530.33962350800	525.33437871200	LOW-MEDIUM RESIDENTIAL	99%
LA MORADA & MOSHER SLOUGH P.S.	760.73961489900	2.83560434994	NOT APPLICABLE/UNKOWN	0%
LA MORADA & MOSHER SLOUGH P.S.	760.73961489900	648.49118019400	LOW-MEDIUM RESIDENTIAL	85%
LA MORADA & MOSHER SLOUGH P.S.	760.73961489900	30.06332792070	HIGH DENSITY RESIDENTIAL	4%
LA MORADA & MOSHER SLOUGH P.S.	760.73961489900	79.34948521640	COMMERCIAL	10%
LEGION PARK & SMITH CANAL P.S.	1866.09513315000	0.49052738172	NOT APPLICABLE/UNKOWN	0%
LEGION PARK & SMITH CANAL P.S.	1866.09513315000	1246.08256226000	LOW-MEDIUM RESIDENTIAL	67%
LEGION PARK & SMITH CANAL P.S.	1866.09513315000	39.47802360380	HIGH DENSITY RESIDENTIAL	2%
LEGION PARK & SMITH CANAL P.S.	1866.09513315000	82.48559737280	ADMINISTRATIVE PROFESSIONAL	4%
LEGION PARK & SMITH CANAL P.S.	1866.09513315000	177.34502434400	COMMERCIAL	10%
LEGION PARK & SMITH CANAL P.S.	1866.09513315000	121.06043666800	INDUSTRIAL	6%
LEGION PARK & SMITH CANAL P.S.	1866.09513315000	195.48102636100	INSTITUTIONAL	10%
LEGION PARK & SMITH CANAL P.S.	1866.09513315000	3.67199542632	PARKS AND RECREATION	0%
LIGHTHOUSE & 5 MILE CREEK P.S.	185.32778925600	1.54080144965	NOT APPLICABLE/UNKOWN	1%
LIGHTHOUSE & 5 MILE CREEK P.S.	185.32778925600	129.52757711200	LOW-MEDIUM RESIDENTIAL	70%
LIGHTHOUSE & 5 MILE CREEK P.S.	185.32778925600	12.95554277440	HIGH DENSITY RESIDENTIAL	7%
LIGHTHOUSE & 5 MILE CREEK P.S.	185.32778925600	11.63458808790	ADMINISTRATIVE PROFESSIONAL	6%
LIGHTHOUSE & 5 MILE CREEK P.S.	185.32778925600	22.52384984460	COMMERCIAL	12%
LIGHTHOUSE & 5 MILE CREEK P.S.	185.32778925600	7.14543285721	PERFORMANCE INDUSTRIAL	4%
LITTLE BEAR CREEK 106	4.49912764004	0.53782883606	NOT APPLICABLE/UNKOWN	12%
LITTLE BEAR CREEK 106	4.49912764004	3.96129880398	LOW-MEDIUM RESIDENTIAL	88%
LITTLE BEAR CREEK 107	16.99444157480	0.26199222791	NOT APPLICABLE/UNKOWN	2%
LITTLE BEAR CREEK 107	16.99444157480	2.40718334073	LOW-MEDIUM RESIDENTIAL	14%
LITTLE BEAR CREEK 107	16.99444157480	4.57176765520	ADMINISTRATIVE PROFESSIONAL	27%
LITTLE BEAR CREEK 107	16.99444157480	9.75349835099	COMMERCIAL	57%
LITTLE BEAR CREEK 109	15.77159234390	0.09434143560	NOT APPLICABLE/UNKOWN	1%
LITTLE BEAR CREEK 109	15.77159234390	1.33152366850	LOW-MEDIUM RESIDENTIAL	8%

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
LITTLE BEAR CREEK 109	15.77159234390	10.78563999450	ADMINISTRATIVE PROFESSIONAL	68%
LITTLE BEAR CREEK 109	15.77159234390	3.56008724533	COMMERCIAL	23%
LITTLE BEAR CREEK 110	21.15005308770	1.00711015387	NOT APPLICABLE/UNKOWN	5%
LITTLE BEAR CREEK 110	21.15005308770	13.49836553010	LOW-MEDIUM RESIDENTIAL	64%
LITTLE BEAR CREEK 110	21.15005308770	3.03734594756	ADMINISTRATIVE PROFESSIONAL	14%
LITTLE BEAR CREEK 110	21.15005308770	3.60723145610	COMMERCIAL	17%
LITTLE BEAR CREEK 124	0.14256341827	0.04013292794	NOT APPLICABLE/UNKOWN	28%
LITTLE BEAR CREEK 124	0.14256341827	0.10243049034	ADMINISTRATIVE PROFESSIONAL	72%
LITTLE BEAR CREEK 127	0.15259125344	0.00533151573	NOT APPLICABLE/UNKOWN	3%
LITTLE BEAR CREEK 127	0.15259125344	0.14725973771	LOW-MEDIUM RESIDENTIAL	97%
LITTLE BEAR CREEK 129	1.11173525023	0.26359334063	NOT APPLICABLE/UNKOWN	24%
LITTLE BEAR CREEK 129	1.11173525023	0.84814190960	LOW-MEDIUM RESIDENTIAL	76%
LITTLE JOHN CREEK 173	6.03784291781	0.15693895589	NOT APPLICABLE/UNKOWN	3%
LITTLE JOHN CREEK 173	6.03784291781	5.87625624182	LOW-MEDIUM RESIDENTIAL	97%
LITTLE JOHN CREEK 173	6.03784291781	0.00464772011	INDUSTRIAL	0%
WER SACRAMENTO & LITTLE BEAR CREEK F	221.24478879700	4.22305819866	NOT APPLICABLE/UNKOWN	2%
WER SACRAMENTO & LITTLE BEAR CREEK F	221.24478879700	202.91640317600	LOW-MEDIUM RESIDENTIAL	92%
WER SACRAMENTO & LITTLE BEAR CREEK F	221.24478879700	7.59309142562	HIGH DENSITY RESIDENTIAL	3%
WER SACRAMENTO & LITTLE BEAR CREEK F	221.24478879700	6.51222882231	COMMERCIAL	3%
MARINER & MOSHER SLOUGH P.S.	102.19434113900	0.07469923201	NOT APPLICABLE/UNKOWN	0%
MARINER & MOSHER SLOUGH P.S.	102.19434113900	102.11964477600	LOW-MEDIUM RESIDENTIAL	100%
MORMON SLOUGH 140	31.24746039940	0.00034351323	NOT APPLICABLE/UNKOWN	0%
MORMON SLOUGH 140	31.24746039940	12.56844078830	HIGH DENSITY RESIDENTIAL	40%
MORMON SLOUGH 140	31.24746039940	7.18894187308	ADMINISTRATIVE PROFESSIONAL	23%
MORMON SLOUGH 140	31.24746039940	11.48973422480	COMMERCIAL	37%
MORMON SLOUGH 141	72.79833562900	0.00098712505	NOT APPLICABLE/UNKOWN	0%
MORMON SLOUGH 141	72.79833562900	72.79734850400	INDUSTRIAL	100%
MORMON SLOUGH 142	483.00762167100	0.00021246385	NOT APPLICABLE/UNKOWN	0%
MORMON SLOUGH 142	483.00762167100	136.76227823400	LOW-MEDIUM RESIDENTIAL	28%
MORMON SLOUGH 142	483.00762167100	0.01013364112	COMMERCIAL	0%
MORMON SLOUGH 142	483.00762167100	346.23502028600	INDUSTRIAL	72%
MORMON SLOUGH 143	19.54875889580	0.00024918709	NOT APPLICABLE/UNKOWN	0%
MORMON SLOUGH 143	19.54875889580	9.16067296467	ADMINISTRATIVE PROFESSIONAL	47%
MORMON SLOUGH 143	19.54875889580	10.23341675150	COMMERCIAL	52%
MORMON SLOUGH 143	19.54875889580	0.15441999251	INDUSTRIAL	1%
MORMON SLOUGH 144	21.42736742420	5.52411279643	ADMINISTRATIVE PROFESSIONAL	26%
MORMON SLOUGH 144	21.42736742420	6.01056797277	COMMERCIAL	28%
MORMON SLOUGH 144	21.42736742420	9.89268665503	INDUSTRIAL	46%
MORMON SLOUGH 145	19.60668474520	14.96571611930	COMMERCIAL	76%
MORMON SLOUGH 145	19.60668474520	4.64096862585	INDUSTRIAL	24%
MORMON SLOUGH 147	142.45120523400	0.10452242072	NOT APPLICABLE/UNKOWN	0%

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
MORMON SLOUGH 147	142.45120523400	63.30824665750	LOW-MEDIUM RESIDENTIAL	44%
MORMON SLOUGH 147	142.45120523400	7.84188818994	COMMERCIAL	6%
MORMON SLOUGH 147	142.45120523400	71.19655226740	INDUSTRIAL	50%
MORMON SLOUGH 148	7.42024793388	3.05384409428	COMMERCIAL	41%
MORMON SLOUGH 148	7.42024793388	4.36640383960	INDUSTRIAL	59%
MORMON SLOUGH 149	6.28882145317	0.01754358799	NOT APPLICABLE/UNKOWN	0%
MORMON SLOUGH 149	6.28882145317	6.27127786517	INDUSTRIAL	100%
MORMON SLOUGH 150	955.46106519700	4.97973398544	NOT APPLICABLE/UNKOWN	1%
MORMON SLOUGH 150	955.46106519700	332.95770653600	LOW-MEDIUM RESIDENTIAL	35%
MORMON SLOUGH 150	955.46106519700	46.98665920570	HIGH DENSITY RESIDENTIAL	5%
MORMON SLOUGH 150	955.46106519700	191.30793985600	COMMERCIAL	20%
MORMON SLOUGH 150	955.46106519700	249.15787364100	INDUSTRIAL	26%
MORMON SLOUGH 150	955.46106519700	130.07110749600	INSTITUTIONAL	14%
MORMON SLOUGH 151	118.12146464600	1.01402268668	NOT APPLICABLE/UNKOWN	1%
MORMON SLOUGH 151	118.12146464600	78.27112699250	LOW-MEDIUM RESIDENTIAL	66%
MORMON SLOUGH 151	118.12146464600	33.74487012210	COMMERCIAL	29%
MORMON SLOUGH 151	118.12146464600	5.09144914953	INDUSTRIAL	4%
MORMON SLOUGH 152	15.14343003900	0.01156652737	NOT APPLICABLE/UNKOWN	0%
MORMON SLOUGH 152	15.14343003900	11.65968812810	LOW-MEDIUM RESIDENTIAL	77%
MORMON SLOUGH 152	15.14343003900	3.47217538359	INDUSTRIAL	23%
MORMON SLOUGH 153	77.31771694210	0.93600125851	NOT APPLICABLE/UNKOWN	1%
MORMON SLOUGH 153	77.31771694210	0.00152114642	LOW-MEDIUM RESIDENTIAL	0%
MORMON SLOUGH 153	77.31771694210	14.48485384570	INDUSTRIAL	19%
MORMON SLOUGH 153	77.31771694210	61.89533925670	INSTITUTIONAL	80%
MORMON SLOUGH 154	298.15174472000	0.10668252576	NOT APPLICABLE/UNKOWN	0%
MORMON SLOUGH 154	298.15174472000	156.60914388000	LOW-MEDIUM RESIDENTIAL	53%
MORMON SLOUGH 154	298.15174472000	2.60125965050	HIGH DENSITY RESIDENTIAL	1%
MORMON SLOUGH 154	298.15174472000	21.18815922590	COMMERCIAL	7%
MORMON SLOUGH 154	298.15174472000	117.64649513200	INDUSTRIAL	39%
MORMON SLOUGH 155	271.28732782400	1.13049544633	NOT APPLICABLE/UNKOWN	0%
MORMON SLOUGH 155	271.28732782400	177.85872889300	LOW-MEDIUM RESIDENTIAL	66%
MORMON SLOUGH 155	271.28732782400	52.35291177230	COMMERCIAL	19%
MORMON SLOUGH 155	271.28732782400	14.66634011670	INDUSTRIAL	5%
MORMON SLOUGH 155	271.28732782400	25.27885876930	INSTITUTIONAL	9%
MORMON SLOUGH 157	101.16000918300	100.03815553600	LOW-MEDIUM RESIDENTIAL	99%
MORMON SLOUGH 157	101.16000918300	1.12185938619	COMMERCIAL	1%
MORMON SLOUGH 158	32.69016012400	0.15091136150	NOT APPLICABLE/UNKOWN	0%
MORMON SLOUGH 158	32.69016012400	6.86984014772	LOW-MEDIUM RESIDENTIAL	21%
MORMON SLOUGH 158	32.69016012400	12.87600989750	COMMERCIAL	39%
MORMON SLOUGH 158	32.69016012400	12.79339871730	INDUSTRIAL	39%
MORMON SLOUGH 159	344.89157483900	237.99422598900	LOW-MEDIUM RESIDENTIAL	69%
MORMON SLOUGH 159	344.89157483900	14.46757503710	HIGH DENSITY RESIDENTIAL	4%
MORMON SLOUGH 159	344.89157483900	27.13107167530	COMMERCIAL	8%
MORMON SLOUGH 159	344.89157483900	65.29869639910	INDUSTRIAL	19%

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
MORMON SLOUGH 162	1.40582529844	0.00000688705	NOT APPLICABLE/UNKOWN	0%
MORMON SLOUGH 162	1.40582529844	1.40581841139	INDUSTRIAL	100%
MOSHER SLOUGH 136	0.58922176309	0.08903669979	LOW-MEDIUM RESIDENTIAL	15%
MOSHER SLOUGH 136	0.58922176309	0.50018506330	COMMERCIAL	85%
MOSHER SLOUGH 137	0.73370494720	0.05919867596	NOT APPLICABLE/UNKOWN	8%
MOSHER SLOUGH 137	0.73370494720	0.48789509032	LOW-MEDIUM RESIDENTIAL	66%
MOSHER SLOUGH 137	0.73370494720	0.18661118092	COMMERCIAL	25%
PACIFIC & 5 MILE CREEK P.S.	228.78983011900	117.49363679900	LOW-MEDIUM RESIDENTIAL	51%
PACIFIC & 5 MILE CREEK P.S.	228.78983011900	29.57210606200	HIGH DENSITY RESIDENTIAL	13%
PACIFIC & 5 MILE CREEK P.S.	228.78983011900	10.18845735890	ADMINISTRATIVE PROFESSIONAL	4%
PACIFIC & 5 MILE CREEK P.S.	228.78983011900	71.53563707350	COMMERCIAL	31%
PLYMOUTH & 5 MILE CREEK P.S.	186.18379820900	1.01064631536	NOT APPLICABLE/UNKOWN	1%
PLYMOUTH & 5 MILE CREEK P.S.	186.18379820900	155.51542845000	LOW-MEDIUM RESIDENTIAL	84%
PLYMOUTH & 5 MILE CREEK P.S.	186.18379820900	4.49457398510	HIGH DENSITY RESIDENTIAL	2%
PLYMOUTH & 5 MILE CREEK P.S.	186.18379820900	0.17108942585	ADMINISTRATIVE PROFESSIONAL	0%
PLYMOUTH & 5 MILE CREEK P.S.	186.18379820900	24.99205716340	COMMERCIAL	13%
PORT OF STOCKTON	679.30293847600	0.00107594163	NOT APPLICABLE/UNKOWN	0%
PORT OF STOCKTON	679.30293847600	22.33168859720	LOW-MEDIUM RESIDENTIAL	3%
PORT OF STOCKTON	679.30293847600	656.97015958900	INDUSTRIAL	97%
PRIVATE	103.81792355400	5.32879596470	NOT APPLICABLE/UNKOWN	5%
PRIVATE	103.81792355400	0.47128993815	LOW-MEDIUM RESIDENTIAL	0%
PRIVATE	103.81792355400	1.09619106248	COMMERCIAL	1%
PRIVATE	103.81792355400	79.48390398670	INDUSTRIAL	77%
PRIVATE	103.81792355400	0.00200385178	INSTITUTIONAL	0%
PRIVATE	103.81792355400	17.43573733620	PARKS AND RECREATION	17%
ROYAL OAKS & LITTLE BEAR CREEK P.S.	479.47999311300	9.92153191911	NOT APPLICABLE/UNKOWN	2%
ROYAL OAKS & LITTLE BEAR CREEK P.S.	479.47999311300	460.08197856800	LOW-MEDIUM RESIDENTIAL	96%
ROYAL OAKS & LITTLE BEAR CREEK P.S.	479.47999311300	0.13445838527	ADMINISTRATIVE PROFESSIONAL	0%
ROYAL OAKS & LITTLE BEAR CREEK P.S.	479.47999311300	9.34202567500	COMMERCIAL	2%
RYDE & SMITH CANAL P.S.	196.90351239700	0.00026165482	NOT APPLICABLE/UNKOWN	0%
RYDE & SMITH CANAL P.S.	196.90351239700	123.87200450700	LOW-MEDIUM RESIDENTIAL	63%
RYDE & SMITH CANAL P.S.	196.90351239700	2.38855717303	HIGH DENSITY RESIDENTIAL	1%
RYDE & SMITH CANAL P.S.	196.90351239700	8.90139957936	PERFORMANCE INDUSTRIAL	5%
RYDE & SMITH CANAL P.S.	196.90351239700	57.79114271910	INDUSTRIAL	29%
RYDE & SMITH CANAL P.S.	196.90351239700	3.95015680642	PARKS AND RECREATION	2%
SAN JOAQUIN RIVER 160	5.47885101010	0.00859854895	NOT APPLICABLE/UNKOWN	0%
SAN JOAQUIN RIVER 160	5.47885101010	5.47025246114	PARKS AND RECREATION	100%
SAN JOAQUIN RIVER 161	4.20429866850	0.18164330945	NOT APPLICABLE/UNKOWN	4%
SAN JOAQUIN RIVER 161	4.20429866850	4.02265535906	PARKS AND RECREATION	96%
SAN JOAQUIN RIVER 166	3.20153380395	0.28571437940	NOT APPLICABLE/UNKOWN	9%
SAN JOAQUIN RIVER 166	3.20153380395	2.91581942455	PARKS AND RECREATION	91%
SAN JOAQUIN RIVER 168	2.26669823232	0.09063436770	NOT APPLICABLE/UNKOWN	4%

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
SAN JOAQUIN RIVER 168	2.26669823232	0.66304001273	LOW-MEDIUM RESIDENTIAL	29%
SAN JOAQUIN RIVER 168	2.26669823232	1.51302385190	PARKS AND RECREATION	67%
SANGUINETTI & CALAVERAS RIVER P.S.	218.03117539000	79.37951834600	LOW-MEDIUM RESIDENTIAL	36%
SANGUINETTI & CALAVERAS RIVER P.S.	218.03117539000	138.65165848000	INDUSTRIAL	64%
SMITH CANAL 102	5.60629304408	0.00002016129	NOT APPLICABLE/UNKOWN	0%
SMITH CANAL 102	5.60629304408	4.92239761603	HIGH DENSITY RESIDENTIAL	88%
SMITH CANAL 102	5.60629304408	0.68387526676	PARKS AND RECREATION	12%
SMITH CANAL 103	7.87329832415	0.00000996956	NOT APPLICABLE/UNKOWN	0%
SMITH CANAL 103	7.87329832415	0.20924026362	LOW-MEDIUM RESIDENTIAL	3%
SMITH CANAL 103	7.87329832415	7.66404809245	HIGH DENSITY RESIDENTIAL	97%
SMITH CANAL 104	16.99496814740	0.00000196107	NOT APPLICABLE/UNKOWN	0%
SMITH CANAL 104	16.99496814740	16.99490579340	LOW-MEDIUM RESIDENTIAL	100%
SMITH CANAL 104	16.99496814740	0.00006039149	HIGH DENSITY RESIDENTIAL	0%
SPANOS WEST P.S.	594.22681359000	344.11817229900	LOW-MEDIUM RESIDENTIAL	58%
SPANOS WEST P.S.	594.22681359000	7.06307800513	COMMERCIAL	1%
SPANOS WEST P.S.	594.22681359000	1.48524841323	OPEN SPACE	0%
SPANOS WEST P.S.	594.22681359000	5.27036165185	PARKS AND RECREATION	1%
SPANOS WEST P.S.	594.22681359000	232.80962782000	NOT APPLICABLE/UNKOWN	39%
STAGECOACH & DUCK CREEK P.S.	258.49582185500	4.30983756897	NOT APPLICABLE/UNKOWN	2%
STAGECOACH & DUCK CREEK P.S.	258.49582185500	254.17053752700	INDUSTRIAL	98%
STAGECOACH & DUCK CREEK P.S.	258.49582185500	0.01545536803	AGRICULTURE	0%
STATE	65.53373794770	0.00053789848	NOT APPLICABLE/UNKOWN	0%
STATE	65.53373794770	16.00894898880	LOW-MEDIUM RESIDENTIAL	24%
STATE	65.53373794770	1.89583492082	ADMINISTRATIVE PROFESSIONAL	3%
STATE	65.53373794770	14.03752449910	COMMERCIAL	21%
STATE	65.53373794770	4.65888008479	PERFORMANCE INDUSTRIAL	7%
STATE	65.53373794770	26.95830352090	INDUSTRIAL	41%
STATE	65.53373794770	1.97370803492	PARKS AND RECREATION	3%
STOCKTON AIRPORT BUSINESS CENTER P.S	855.48907254400	2.04961297362	NOT APPLICABLE/UNKOWN	0%
STOCKTON AIRPORT BUSINESS CENTER P.S	855.48907254400	179.13559523900	LOW-MEDIUM RESIDENTIAL	21%
STOCKTON AIRPORT BUSINESS CENTER P.S	855.48907254400	0.98986543959	COMMERCIAL	0%
STOCKTON AIRPORT BUSINESS CENTER P.S	855.48907254400	649.91570542600	INDUSTRIAL	76%
STOCKTON AIRPORT BUSINESS CENTER P.S	855.48907254400	23.39829203080	INSTITUTIONAL	3%
SUTTER & CALAVERAS RIVER P.S.	363.85383666200	0.29284592263	NOT APPLICABLE/UNKOWN	0%
SUTTER & CALAVERAS RIVER P.S.	363.85383666200	243.05994694100	LOW-MEDIUM RESIDENTIAL	67%
SUTTER & CALAVERAS RIVER P.S.	363.85383666200	27.39028064740	HIGH DENSITY RESIDENTIAL	8%
SUTTER & CALAVERAS RIVER P.S.	363.85383666200	26.02377716880	ADMINISTRATIVE PROFESSIONAL	7%
SUTTER & CALAVERAS RIVER P.S.	363.85383666200	3.08421719283	COMMERCIAL	1%
SUTTER & CALAVERAS RIVER P.S.	363.85383666200	0.00657473531	INDUSTRIAL	0%
SUTTER & CALAVERAS RIVER P.S.	363.85383666200	1.20029731146	INSTITUTIONAL	0%
SUTTER & CALAVERAS RIVER P.S.	363.85383666200	62.79588642100	PARKS AND RECREATION	17%
SWENSON & 5 MILE CREEK P.S.	670.82561983500	1.30171169635	NOT APPLICABLE/UNKOWN	0%
SWENSON & 5 MILE CREEK P.S.	670.82561983500	452.75431943300	LOW-MEDIUM RESIDENTIAL	67%
SWENSON & 5 MILE CREEK P.S.	670.82561983500	8.28042159682	HIGH DENSITY RESIDENTIAL	1%
SWENSON & 5 MILE CREEK P.S.	670.82561983500	7.90091589480	COMMERCIAL	1%

City of Stockton - Summary of Land Uses within Drainage Basins

Drainage Basin	Drainage Basin Acres	Land Use Acreage	Land Use Description	Land Use % of Basin Acreage
SWENSON & 5 MILE CREEK P.S.	670.82561983500	200.58826412700	PARKS AND RECREATION	30%
THORTON & MOSHER SLOUGH P.S.	147.49255624400	1.05388494652	NOT APPLICABLE/UNKOWN	1%
THORTON & MOSHER SLOUGH P.S.	147.49255624400	127.61220450100	LOW-MEDIUM RESIDENTIAL	87%
THORTON & MOSHER SLOUGH P.S.	147.49255624400	18.82645962300	COMMERCIAL	13%
TURNPIKE & WALKER SLOUGH P.S.	1490.66501377000	3.86219646323	NOT APPLICABLE/UNKOWN	0%
TURNPIKE & WALKER SLOUGH P.S.	1490.66501377000	1067.22725582000	LOW-MEDIUM RESIDENTIAL	72%
TURNPIKE & WALKER SLOUGH P.S.	1490.66501377000	8.98913854454	HIGH DENSITY RESIDENTIAL	1%
TURNPIKE & WALKER SLOUGH P.S.	1490.66501377000	188.61645282400	COMMERCIAL	13%
TURNPIKE & WALKER SLOUGH P.S.	1490.66501377000	217.27945409500	INDUSTRIAL	15%
TURNPIKE & WALKER SLOUGH P.S.	1490.66501377000	4.69053181274	PARKS AND RECREATION	0%
WEBER SLOUGH 171	30.35820707070	8.57042132217	COMMERCIAL	28%
WEBER SLOUGH 171	30.35820707070	0.70180397627	INDUSTRIAL	2%
WEBER SLOUGH 171	30.35820707070	0.24697424331	INSTITUTIONAL	1%
WEBER SLOUGH 171	30.35820707070	20.83900896380	AGRICULTURE	69%
WEST LANE & CALAVERAS (NORTH) P.S.	437.09292929300	248.98740892500	LOW-MEDIUM RESIDENTIAL	57%
WEST LANE & CALAVERAS (NORTH) P.S.	437.09292929300	35.88591875610	HIGH DENSITY RESIDENTIAL	8%
WEST LANE & CALAVERAS (NORTH) P.S.	437.09292929300	20.84394674660	ADMINISTRATIVE PROFESSIONAL	5%
WEST LANE & CALAVERAS (NORTH) P.S.	437.09292929300	131.37565773500	COMMERCIAL	30%
WEST LANE & CALAVERAS (SOUTH) P.S.	170.52266988100	51.67761684010	LOW-MEDIUM RESIDENTIAL	30%
WEST LANE & CALAVERAS (SOUTH) P.S.	170.52266988100	118.84505046300	INDUSTRIAL	70%
WESTERN PACIFIC INDUSTRIAL PARK P.S.	596.66179981600	9.83311839640	NOT APPLICABLE/UNKOWN	2%
WESTERN PACIFIC INDUSTRIAL PARK P.S.	596.66179981600	0.86828671929	LOW-MEDIUM RESIDENTIAL	0%
WESTERN PACIFIC INDUSTRIAL PARK P.S.	596.66179981600	2.24760897331	PERFORMANCE INDUSTRIAL	0%
WESTERN PACIFIC INDUSTRIAL PARK P.S.	596.66179981600	583.71278142300	INDUSTRIAL	98%
WESTON RANCH P.S.	1710.30633609000	31.34287709930	NOT APPLICABLE/UNKOWN	2%
WESTON RANCH P.S.	1710.30633609000	1444.19821246000	LOW-MEDIUM RESIDENTIAL	84%
WESTON RANCH P.S.	1710.30633609000	68.01362453370	HIGH DENSITY RESIDENTIAL	4%
WESTON RANCH P.S.	1710.30633609000	69.64078734590	COMMERCIAL	4%
WESTON RANCH P.S.	1710.30633609000	74.86967721890	OPEN SPACE	4%
WESTON RANCH P.S.	1710.30633609000	3.89998890297	INDUSTRIAL	0%
WESTON RANCH P.S.	1710.30633609000	18.34116565870	AGRICULTURE	1%
YARMOUTH & MOSHER SLOUGH P.S.	179.90933195600	2.30787726013	NOT APPLICABLE/UNKOWN	1%
YARMOUTH & MOSHER SLOUGH P.S.	179.90933195600	138.71270186900	LOW-MEDIUM RESIDENTIAL	77%
YARMOUTH & MOSHER SLOUGH P.S.	179.90933195600	21.44482966490	HIGH DENSITY RESIDENTIAL	12%
YARMOUTH & MOSHER SLOUGH P.S.	179.90933195600	17.40161640680	COMMERCIAL	10%
YARMOUTH & MOSHER SLOUGH P.S.	179.90933195600	0.04230388521	PERFORMANCE INDUSTRIAL	0%

Attachment B

Mormon Slough and Smith Canal Watershed Maps

Maps are available for review at Central Valley Water Board offices